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Construction Engineering Research Laboratory

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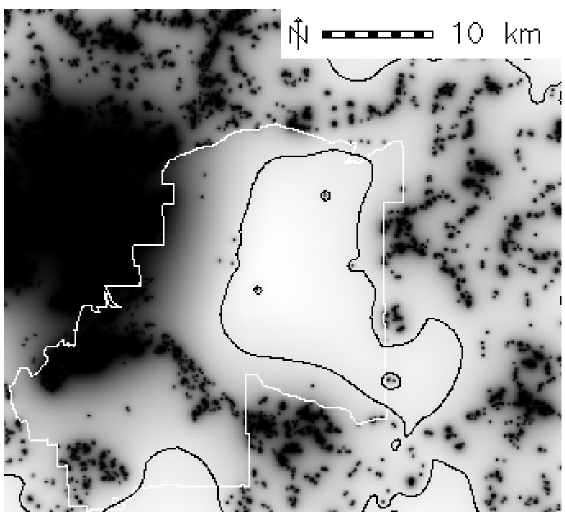
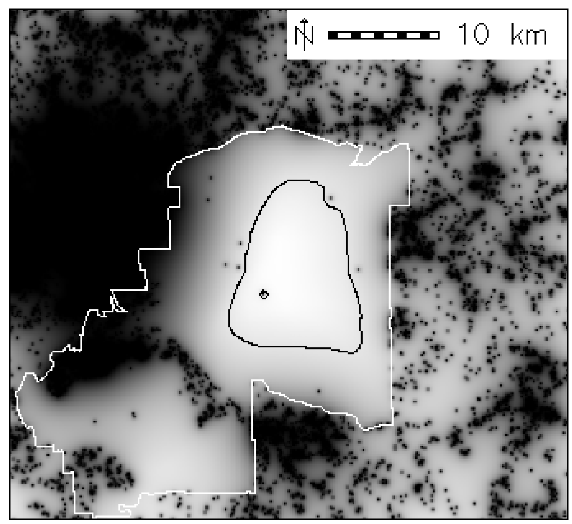
Engineer Research and Development Center

Predicting Future Training Opportunities Using the Land-Use Evolution and Impact Assessment Model

James D. Westervelt, Sarah B. Nemeth, Michael J. White, Michael R. Kemme, Dawn A. Morrison, and Christa Eastgate

October 2007





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Abstract: The future training/testing capacities of military installations and their surrounding regions are increasingly based on today's smart regional planning in collaboration with surrounding cities, counties, and states. Developing urban patterns around installations can be steered in a manner that ensures the continued viability of the installation to support present and future missions. Researchers have developed a two-step process to link proposed regional plans to future training/testing opportunities. The first step is to project future urban patterns that are likely to develop. This document covers the second step: identifying where military training will be tolerated, in future urban patterns, by people living near installations. It includes discussions of mathematical modeling approaches that convert projected urban patterns into maps of where noise, dust, and smoke will be tolerated by surrounding communities and where light from the communities will not interfere with night training.

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Preface

This work was conducted for the Strategic Environmental Research and Development Program (SERDP) Office under Work Unit CS-1257, "The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustaining Military Communities." The technical monitor was Dr. Robert W. Holst, Compliance and Conservation Program Manager, SERDP. The Executive Director of SERDP was Bradley P. Smith.

The work was performed by the Engineering Processes Branch (CF-N) of the Facilities Division (CF), the Land and Heritage Conservation Branch (CN-C), the Environmental Processes Branch (CN-E), the Ecological Processes Branch (CN-N), and the Business Processes Branch (CN-B) of the Installations Division (CN). The ERDC-CERL Project Manager was Dr. James D. Westervelt. At the time this report was prepared, L. Michael Golish was Chief, CF, and Dr. John T. Bandy was Chief, CN. Dr. William D. Severinghaus was Technical Director, Sustainable Ranges and Lands. The Deputy Director of ERDC-CERL was Dr. Kirankumar V. Topudurti and the Director was Dr. Ilker R. Adiguzel.

The Commander and Executive Director of ERDC was COL Richard B. Jenkins and the Director was Dr. James R. Houston.

Introduction

Background

Military installations with training and testing missions have historically been located in areas surrounded by agricultural land or forests, remote from civilian residential developments. The noise, dust, smoke, and radio frequency (RF) interference produced by military training and testing originally had little impact on adjacent lands. Over time, however, land ownership and use near installations has changed. These changes tend to be shaped by regional planning and investment decisions that influence residential settlement patterns. Also, new transportation modes and communications technologies have made many previously remote areas more attractive to urban development than in the past. The result has been a steady increase in civilian activities near the boundaries of military installations.

As residential patterns follow new economic development closer to installation boundaries, conflicts between residents and military training and testing missions have risen steadily. Incompatible land uses on opposite sides of the installation fence line have led nearby land owners to demand that installations curtail mission-related activities that create a nuisance to residents.

Being the largest land holder in the Department of Defense (DoD), the U.S. Army is more affected than the other military services by urban encroachment. As the Army Transformation initiative, Base Realignment and Closure (BRAC), new weapons system implementations, and large, multiservice training operations take place, the long-term sustainability of installations depends on maintaining the ability to continue current training activities and to accommodate new training and testing missions as they emerge.

DoD officials have testified before Congress that the military services face growing constraints on their ability to conduct realistic training and testing due to urban growth close to installation boundaries. Some of the most common conflicts affecting military training and readiness activities include noise, air pollution, competition for RF spectra, and effects on endangered species habitat on installations. According to a Government Accountability Office (GAO) report published in 2002:

> Whenever possible, the services work around these issues by modifying the timing, tempo, and location of training, as well as the equipment used. However, defense officials have expressed concern that these workarounds are becoming increasingly difficult and costly and that they compromise the realism essential to effective training (GAO-02-614, June 2002, p 1).

In December 2002, Congress passed the National Defense Authorization Act of 2003, Public Law 107-314, which required the Secretary of Defense:

> to develop and maintain an inventory of training ranges for each of the armed forces, which identifies all training capacities, capabilities, and constraints at each training range, and it required the Secretary of Defense to submit a report on his plans to improve the system for reporting the impact that training restraints have on readiness (GAO-06-29R, p 2).

Section 366 of the law also mandated that the GAO evaluate the Office of the Secretary of Defense's (OSD's) annual reports and submit its findings to Congress.

In November 2003, Congress enacted the National Defense Authorization Act of 2004, which required the Secretary of Defense to conduct a study describing and analyzing "the types and degree of such civilian community encroachment at each military installation" where civilian encroachment is occurring (Public Law 108-136, National Defense Authorization Act for Fiscal Year 2004, Section 320).

DoD submitted the reports as directed in February 2004 and July 2005. The GAO reviewed the reports and issued its findings in two reports. GAO-06-29R (October 2005) found that neither OSD report documented training constraints related to encroachment as required (p 8). It also found that the July 2005 OSD report lacks "an assessment of current and future training range requirements" (p 10) and "recommendations for legislative or regulatory changes to address encroachment or other training constraints” (p 12).

The incomplete response to Congressional information requirements is probably, in significant part, due to a lack of data processing and analytical tools that are suitable for providing quantitative answers. Just as importantly, the lack of such tools leaves installation commanders in the position of making educated guesses, rather than quantitative projections, about future training needs and constraints. Although analytical tools are available that can simulate and predict the impact of current military training and testing on neighboring communities, those tools are not well suited to analyze future opportunities for and constraints on training in the context of projected urban development. It can be seen, therefore, that DoD requires new methodologies and tools to help identify potential conflicts between prospective future training missions and projected urban growth near installations. The two basic requirements for such predictive planning and management tools are to:

1. reliably project future urban settlement patterns
2. quantitatively predict potential land-use incompatibilities between future training and testing activities versus those projected new residential communities located near the installation.

In connection with the first requirement, various automated tools for projecting urban and regional development patterns are available (e.g., the Land use Evolution and impact Assessment Model, or LEAM*). They have been documented elsewhere (Westervelt and MacAllister 2006) and are not addressed here.

In connection with the second requirement, the U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) has investigated and demonstrated methodologies for identifying potential conflicts between potential future military and civilian land uses. The general goal of the work has been to help installation commanders and planners understand the impact on the surrounding area of future training and testing activities conducted at given locations on the installation. That information can be used to help military decision makers identify the best locations for future training opportuni-

* Developed by the University of Illinois at Urbana-Champaign in partnership with the National Science Foundation, U.S. Army Engineer Research and Development Center, and others (www.leam.uiuc.edu/).

ties while avoiding locations likely to generate complaints from surrounding communities about noise, dust, and other nuisance effects. Furthermore, the data may be used as part of the greater regional planning process to avoid encroachments that could constrain future mission-critical training and testing activities.

Objective

The purpose of this special report is to summarize the findings of ERDC-CERL investigations into methods and technologies that will help military decision makers identify the impacts of future training and testing activities, as conducted at various locations, on residential settlements projected to be constructed over the next several decades.

Approach

Two different approaches were considered to predict future encroachment challenges and issues. The goal of the first was to predict the future layout and structure of military installations. Approaches for predicting on-installation land use included: (1) consulting with the experts (e.g., master planning office, top installation leadership, supporting regional offices, and headquarters level installation planners), (2) maintaining current land-use patterns, (3) applying land-use sustainability modeling, and (4) using doctrine-based creation of patterns. Success would mean that currently available tools and analyses that convert training and testing schedules to off-installation impact patterns would be useful. However, it became clear that the ability to predict future installation land-use patterns required the virtually impossible ability to predict future BRAC and Army-leadership decisions. Instead, the approach of predicting changes in military training and testing opportunities as a result of predicted urban patterns was chosen.

The technical report "Approaches for Evaluating the Impact of Urban Encroachment on Installation Training/Testing" (ERDC/CERL TR-04-4) summarizes these arguments and resulting approaches. The fundamental question explored in that report was:

> What is the best way to approach analyzing projected urban growth patterns around military installations with respect to changes in community pressure to restrict training and testing, and how might the

approaches be different when addressing short (1 – 5 year), medium (5 – 15 year), and long (20 – 50 year) range planning issues?

ERDC/CERL TR-04-4 identified and analyzed various approaches for predicting urban land-use change off installations, land-use change on installations, the impact of training and testing on surrounding communities, and the impact of urban growth on the future options to train and test on installations. The research team set out to develop spatial analysis approaches that would convert urban pattern maps to maps showing where the inhabitants would tolerate noise, dust, smoke, and RF interference from military training and testing. For each type of disturbance, one or more of the authors developed literature-based algorithms that are documented here. The algorithms were then captured in geographic information system (GIS) spatially explicit software.

These analysis tools can help determine potential training opportunities in response to urban encroachment. Chapter 1 provides a review of indicators of land-use incompatibilities at two installations based on historic complaints. Chapter 2 discusses the development of a GIS-analysis tool for forecasting where dust and smoke generating activities could take place with respect to historic, current, or projected urban patterns. Chapter 3 discusses a similar capability with respect to identifying areas that might support military training and testing noise.

1 Identifying Specific Indicators of Land-Use Incompatibilities

Christa J. Eastgate and Dawn A. Morrison

Introduction

Encroachment from urban development is one of the largest problems facing the military and in particular the Army as the largest land holder of the service branches. Encroachment is defined by the Department of Defense (DoD) as any external factor that threatens or constrains testing and training activities on military ranges and installations (Senior Readiness Oversight Council 2001). Further, "many encroachment issues result from or are exacerbated by population growth and urbanization," and the "DoD is particularly affected because urban growth near 80 percent of its installations exceeds the national average" (GAO-02-614, p 9). As for the national average, the population living in metropolitan areas grew from 28 percent in 1910 to 80 percent in 2000 and the current urban population is expected to grow by 29 percent between 2000 and 2025 (Ewing et al. 2005; Hobbs and Stoops 2002; U.S. Census Bureau 2000). As a result, a direct correlation exists between urban sprawl and the loss of training and testing capacity due to conflict arising from incompatible land uses between the military and its growing civilian neighbors.

The ever-increasing proximity of civilian populations to military installations over the past few decades has greatly exacerbated land-use incompatibilities, particularly for the Army. Historically, installations were built in areas that had very little urban development, but as population growth and urban development increased, civilian communities and developers advanced towards installations in search of less expensive land values and relaxed zoning laws. This encroachment brought residential communities in close contact with military training ranges, and in some cases, directly to the fence line.

> The sum effect has been that Army installations, once far from the public view, are now often in the midst of large urban areas. Our training practices bring with them noise, dust, the expenditure of munitions, and ground activities that can be viewed as a nuisance and

> annoyance to those who have become our neighbors (Van Antwerp 2001).

While military doctrine (at least historically) dictates a reactive posture toward enemy threats, urban encroachment is one threat in which the U.S. military must be proactive (it is too late for pre-emptive action) if it desires to maintain its philosophy of having its soldiers "train as they fight." Recognizing the critical issue presented by urban encroachment and the ever-increasing spatial relationship between military and urban communities, there is a clear need to identify specific indicators of land-use incompatibilities. These indicators can then be used to anticipate and perhaps mitigate the negative effects of urban encroachment and facilitate training range sustainability.

Methodology

A multidisciplinary team identified and explored what specific indicators exist that may reflect and can be used to measure the degree of urban and military land-use incompatibilities. It was postulated that installation complaint records would be the best source of readily available and non-invasive* information on land-use incompatibility indicators. Community complaints are one way land-use incompatibility issues (e.g., noise, property damage, and smoke) are expressed.

As such, the research was structured around the database development of historic complaint records. Time and funding constraints allowed for the development of complaint databases for only two installations. The two study sites selected for this project were Fort Benning, GA and Fort Carson, CO. They were chosen based on several factors, including encroachment level, number of estimated complaints, and reputation of the installation as a data source. Preliminary research was conducted into the primary land-use incompatibilities at the selected installations to assist in identifying potential data sources. This research formed the basis for ensuing interviews, archival research, and on-site research. The databases were constructed using an installation's complaint records, which were augmented with data culled from other sources such as environmental compliance documents, local newspapers, planning commission and zoning

* Methods were sought that did not require surveys of local populations or other time-intensive data gathering methods.

board records, local chamber of commerce records, and the offices of state and federal legislative representatives.

Completed databases were then analyzed to determine what insight they provided into land-use incompatibility. This involved comparing and contrasting the substantive content of the two databases, as well as evaluating the qualitative nature of the data. Of particular interest was the impact, or in certain cases, lack thereof, of larger political events and sociological trends on the frequency, as well as nature, of the complaints contained in the constructed database.

Additional analysis focused on whether or not the historic complaint records, which were anticipated to be largely qualitative in nature, could be quantified and spatially expressed so as to support GIS-based demographic analysis. Demographic analysis could reveal the existence of any significant trends indicative of a greater underlying process that, in turn, would increase understanding of the various ways land-use incompatibilities are manifested in public and private discourse. Quantifying and spatially expressing the complaint database will serve as the foundation for subsequent work. In particular, it will contribute to predictive models for identifying and proactively addressing future land-use incompatibilities between military installations and their civilian neighbors.

Study sites

One study site was Fort Benning, located just outside Columbus, GA. Fort Benning occupies 184,000 acres, has a population of 11,737, and serves as an infantry center and school. The influence of Fort Benning is realized in two states, with Fort Benning considered part of a tri-community area encompassing Phenix City, AL, Columbus, GA, and the Chattahoochee Valley (Figure 1.1), all of which are comprised in the Columbus Metropolitan Statistical Area (MSA), population 274,624 (U.S. Census Bureau 2000). Despite being situated in close proximity to several major cities, Fort Benning's closest affiliation is with the Columbus area, where it is the primary employer with approximately 44,000 employees. Likewise, its economic impact on the area totals more than $2 billion in recent years (Nesbitt 2006).

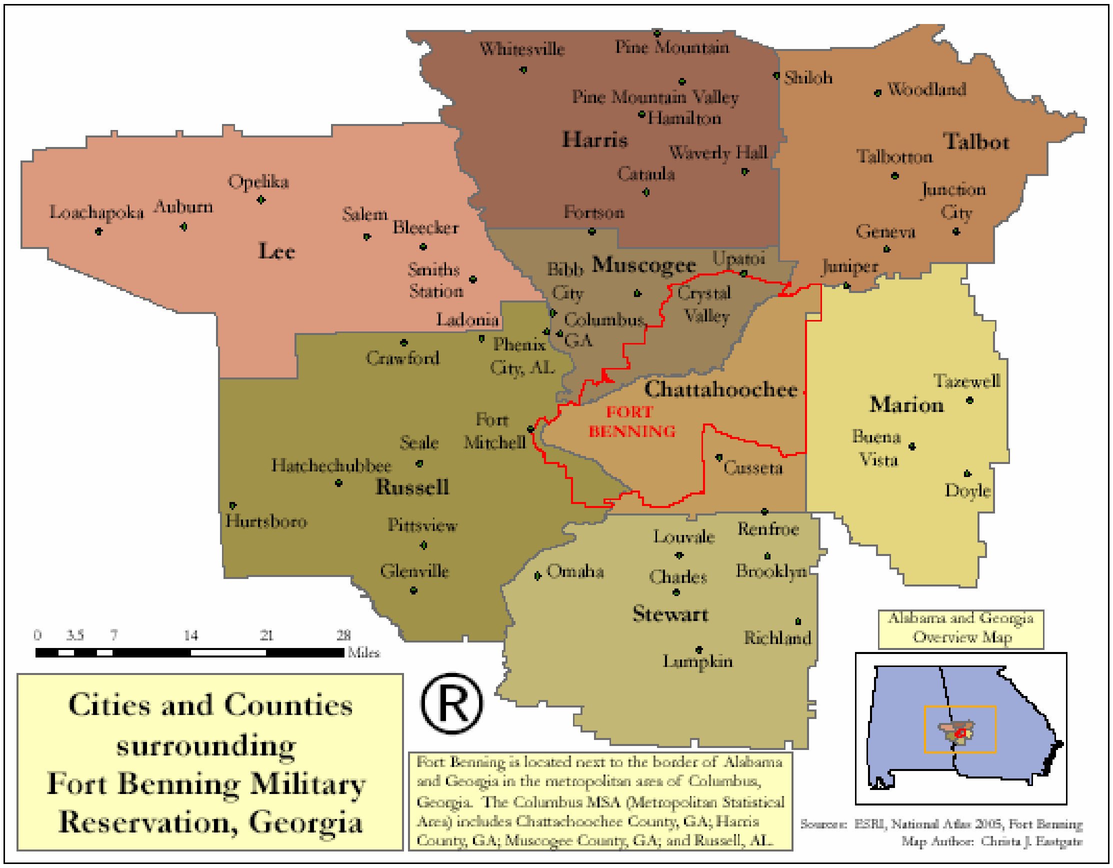

Figure 1.1. Cities and counties surrounding Fort Benning Military Reservation, GA.

Although the area traditionally maintains a good relationship with its Army neighbor, Fort Benning has been identified as an Army installation threatened by encroachment (Fort Benning 2004; Greater Columbus Georgia Chamber of Commerce 2004; Smith 2004). In response to both internal and external encroachment threats, Fort Benning began working to establish an Army Compatible Use Buffer (ACUB) plan. The ACUB's intent was to provide for the continuation of training and conservation on the installation. Fort Benning also worked with the Greater Columbus Consolidated Chamber of Commerce to create a Joint Land Use (JLUS) plan intended to implement buffer zones, land exchanges, noise easements, realtor disclosures, and improved building codes. These ongoing joint efforts, in conjunction with the available demographic data of surrounding communities, made Fort Benning an excellent study site for this research, providing a comprehensive and diverse set of data sources.

The other study site, Fort Carson, is located in the east-central portion of Colorado at the foot of the Rocky Mountain Front Range. It has a population of 10,566, and is home to the 7th Infantry Division and Mountain Post

Team.* The majority of Fort Carson's 137,404 acres straddles El Paso and Pueblo counties, with a small portion of land located in Fremont County (Figure 1.2). The installation is located 75 miles south of Denver, and is bordered by Colorado Springs on the north, state highway 115 on the west, private land on the south, and interstate 25 to the east. Land uses adjacent to Fort Carson include municipal, residential, agricultural, industrial, and other private land uses.

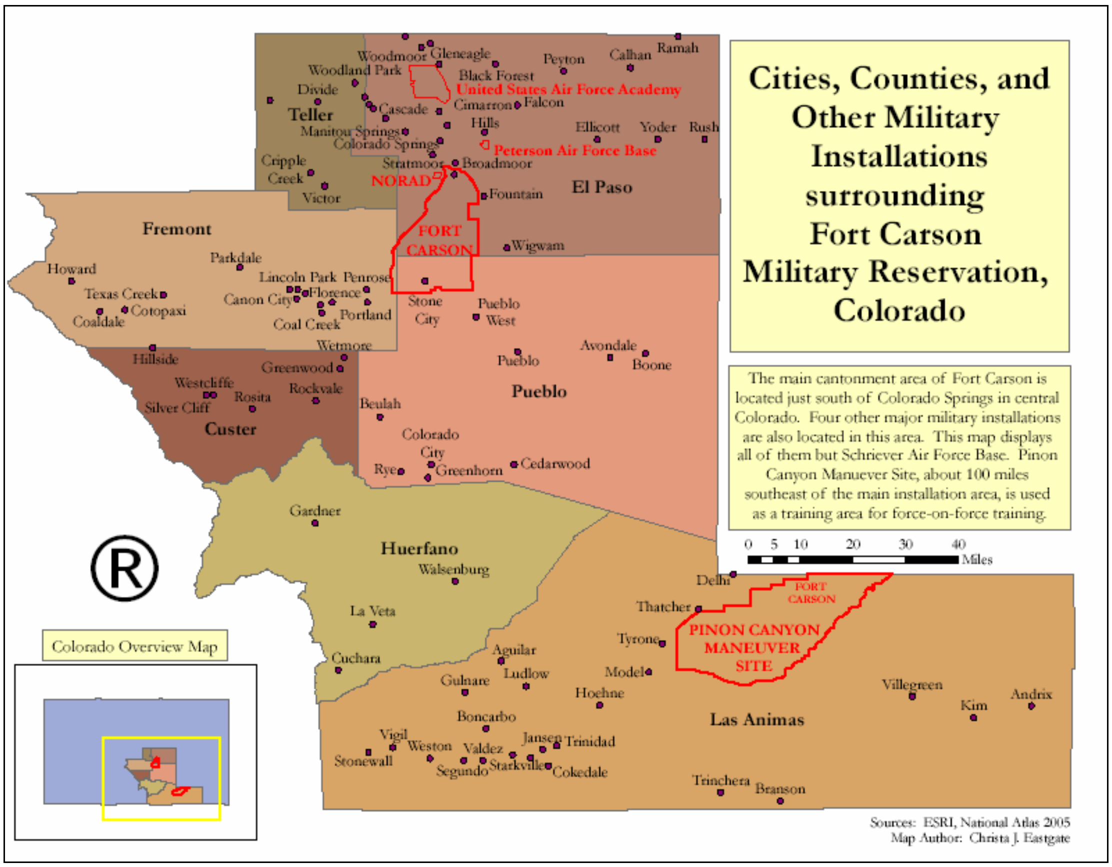

Figure 1.2. Cities, counties, and other military installations surrounding Fort Carson Military Reservation, Colorado.

According to the U.S. Census Bureau, El Paso County was the fastest growing county in Colorado in 2000. In 2005 it was the 15th fastest growing county in Colorado; however, the growth remains high at 6.5%. Although Pueblo County, with a population of 141,172, is not nearly as populated as El Paso County, with a population of 516,929, it is growing at a compara-

* The Piñon Canyon Maneuver Site, containing 237,000 acres and located about 100 miles southeast of Fort Carson, is where Fort Carson conducts force-on-force training and is considered part of Fort Carson. However, this research will focus primarily on the main cantonment area. Figure 1.2 displays the location of this site as well as the surrounding communities and counties for reference.

ble rate of 5.4%. In 2005, it was the 24th fastest growing county in Colorado (Greater Colorado Springs Chamber of Commerce 2005; U.S. Census Bureau 2000). The largest city in the Fort Carson area is Colorado Springs with a population 360,890. It is also the second largest city in Colorado and one of the fastest growing cities in the nation (Pikes Peak Country Attractions Association 2005). Although Colorado Springs is the most important economic and population center for the area, several other communities surround the installation. Many of these communities are primarily residential in nature, and several are within 1 mile of Fort Carson's fence line. Additionally, several new exclusive developments are being built near the Turkey Creek Recreation Area on Fort Carson's western boundary. This rapid residential growth has raised the potential for a variety of land-use incompatibilities between urban and military communities.

In many ways, Fort Carson's encroachment issues are similar to Fort Benning's, but there is one very important difference: Fort Carson is situated in close proximity to four other important military installations, including the U.S. Air Force Academy, North American Aerospace Defense Command (NORAD), Peterson Air Force Base, and Schriever Air Force Base (see Figure 1.2). The overwhelming presence of strategically vital military installations in the central Colorado area result in a community predominantly oriented to the military in nearly every facet. Indeed, the military is the largest employer in the Colorado Springs area. However, the high concentration of military installations in conjunction with the rapid growth and urban development in the area has resulted in Fort Carson frequently being on the Base Realignment and Closure (BRAC) lists.*

Like Fort Benning, Fort Carson's civilian community has been actively involved in mitigating the negative effects of testing and training in order to retain the economic benefits the installation brings. During 1994 and 1995, the Colorado Springs community developed and executed the largest privately funded retention effort in the country, aptly called *Keep Carson*. According to the Colorado Springs Chamber of Commerce, "the military leadership supported retaining Fort Carson because of its irreplaceable training ranges and because they recognized the welcome environment for soldiers, so they never recommended closure of Fort Carson" (Greater

* Through BRAC, DoD plans to reduce excess capacity of military installations, to realign various functions between installations, to downsize personnel and activities, and to close unnecessary facilities. Much of the decision making will revolve around the effects of urban encroachment surrounding a given installation and the degree of incompatibility between civilian and military communities.

Colorado Springs Chamber of Commerce 2005). Another important civilian entity ensuring a positive relationship with Fort Carson was the Defense Mission Task Force (DMTF). DMTF helps resolve problems identified by the military requiring “civilian community support and assistance…, assists with improving ties between the military bases and the community, and keeps informed of the military's privatization of various functions within their structure” (Greater Colorado Springs Chamber of Commerce 2005).

Forts Benning and Carson provided very different mechanisms for encroachment mitigation. While each installation had similar land-use incompatibility issues, their relationships with the surrounding community were substantively different. This, in turn, allowed for a diversity of results between each installation’s complaint record database.

Data collection and sources

Every Army installation is mandated to keep and maintain a record of community complaints registered with installation offices. As this was the most readily available data source, it formed the foundation of each installation’s complaint record database. This mandate, however, did not include standardized collection, organization, or management methods, leaving individual installations to devise their own methods. As a result, Forts Benning and Carson offered two vastly different collection experiences in terms of how the data were organized and formatted. Furthermore, although data sources identified for both installations were similar in nature, they varied in clarity, quality, comprehensiveness, and type (i.e., quantitative versus qualitative) (Table 1.1).

Table 1.1. Comparative data sources.

	Quantitative	Qualitative
Fort Benning	Historic complaint records: 1995-2004 DMPRC community comments	DMPRC community comments Columbus Chamber of Commerce Office of the Staff Judge Advocate ACUB State and federal representatives Ledger-Enquirer WRBL-TV
Fort Carson	Historic complaint records: 1997-2004	Colorado Springs Chamber of Commerce Colorado Springs City Planning Office The Gazette The Chieftain El Paso County DECAM Piñon Canyon Environmental Assessment PAO

The bulk of Fort Benning's data was collected from the Air/Noise Programs Manager of the Environmental Management Division, which was responsible for collecting and managing all installation complaints. The data were largely quantitative, possessing the greatest temporal and spatial attributes of all data gathered. Records were organized by year and complaint type, and mapped in a GIS. Quantitative data for Fort Benning was also found in the community comments section of the Environmental Impact Statement (EIS) prepared, in compliance with federal law, for a proposed Digital Multi-Purpose Range Complex (DMPRC). As part of the EIS, Fort Benning had to provide alternative siting plans for the range, evaluate the environmental impact of all the proposed alternatives, and allow for community and stakeholder comments and feedback on the plan and its alternatives. In this particular EIS, comments were received both in formal meeting sessions and from correspondence by mail, e-mail, and telephone. Also, public comments provided both qualitative and quantitative data as the comments were recorded with an address, thus enabling spatial expression. As a result, insight into land-use incompatibilities in the greater Columbus area provided by these comments demonstrated some of the most important effects of military testing and training on civilian populations.

The entirety of Fort Benning's quantitative data derived from installation sources; however, qualitative data sources emanated from installation and civilian agencies, much of it from interviews with military and civilian personnel.[*] Although lacking specific spatial metrics, the qualitative data provided ample and useful information about land-use incompatibilities in the area, yielding essential information about the community's reaction to the military presence.

Data collection at Fort Carson offered a vastly different experience. Data sources were more limited and the data were less organized and lacked a robust spatial component. For example, many of the recorded complaints lacked a spatial identifier in the form of an address and, where an address was included, it was usually vague or incomplete. As with Fort Benning, the primary data source was the historic complaint record, which proved to be the only source of quantitative data. At Fort Carson, the Public Affairs Office (PAO) managed these records. Unlike Fort Benning, however, the records were not well organized, well maintained, or incorporated in a GIS. Instead, individual records were often incomplete and illegible, suggesting a strong likelihood that the data set itself was incomplete. These records also lacked consistency. It is interesting to note that these records appeared to increase in intensity over the years, yet frequency of complaints recorded decreased.[†] Nevertheless, the records contained both quantitative and qualitative data and shed insight on land-use incompatibilities in the Fort Carson area.

Additional qualitative data for Fort Carson derived from interviews with civilian and installation officers, as well as from online sources.[‡] Information from the Directorate of Environmental Compliance and Management (DECAM) office, the agency responsible for resolving and mitigating complaints issued to the installation, provided another qualitative data source.

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[*] Sources included the Office of the Staff Judge Advocate, the Fort Benning Encroachment Plan - Army Compatible Use Buffer (ACUB), state and federal legislative representatives, the Columbus Chamber of Commerce, and local media outlets, particularly the local newspaper, *Ledger-Enquirer*, the local National Broadcasting Company affiliate, *WRBL*, and public comments from the proposed DMPRC.

[†] Research revealed that this trend may have been due to poor record keeping, rather than an actual reduction in the frequency of complaints. Preliminary investigations into complaint records at Fort Carson revealed a shaky mechanism for submitting all complaints to official documentation. Research found that some PAO staff simply did not record the calls they received if they deemed them unimportant. Because the PAO staff member willingly admitted he did not record all the calls received, it was logical to conclude that complaint records kept by PAO was incomplete. Further collection and maintenance of complaint records was haphazard at best (many complaints were recorded on post-it notes placed inside a folder). Thus, the lower numbers of complaints despite the increasing frustration expressed in the complaint records implied that not all complaints received were actually placed into the installation record.

[‡] These sources included the Military Affairs division of the Colorado Springs Chamber of Commerce, the Colorado Springs City Planning Office, the Colorado Springs newspaper, the *Gazette*, the Pueblo newspaper, the *Chieftain*, El Paso County, the Fort Carson DECAM, and the Fort Carson PAO.

Data from this office came from the Environmental Assessment document for a proposed project at the Piñon Canyon Maneuver Site. This data, in the form of community comments, proved quite limited in scope as it lacked both a spatial component (i.e., an address) and comprehensiveness —the document merely summarized the comments made at the meetings rather than recording them individually. These data were, nevertheless, included in the database.

For Forts Benning and Carson, the data sources identified and the data collection experience revealed the complexity of recording, collecting, and using data to demonstrate land-use incompatibilities. These complexities were further compounded by poor data gathering and management, particularly in the case of Fort Carson. Larger sociopolitical events further impacted and complicated the data collection experience. One valuable lesson learned was that the relationship between installations and their surrounding communities did not evolve or occur within a vacuum, nor were they affected by events that occurred solely within the spatial political boundaries of the installation and communities. Two major events significantly skewed the data collected: the terrorist attacks of September 11, 2001, and the resulting War on Terrorism.

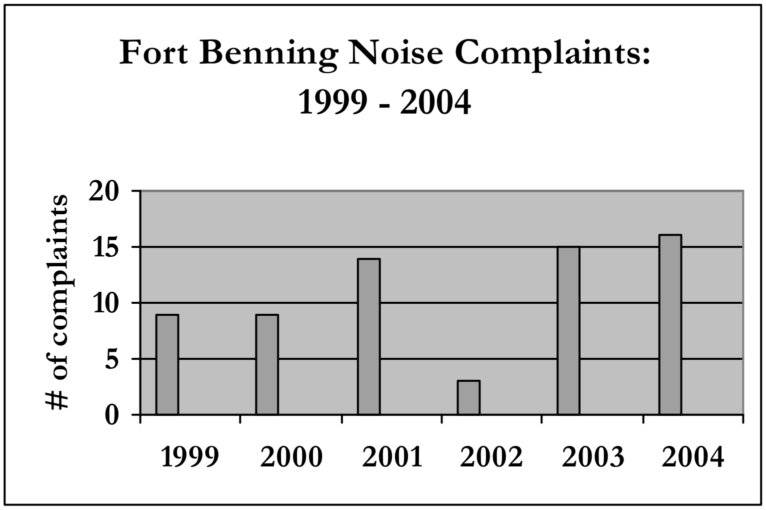
In the atmosphere of intensive patriotism after September 11, several installation agencies at both Fort Benning and Fort Carson noted a drastic reduction in complaints. The heightened sense of patriotism evidently correlated to a heightened tolerance for military training and testing practices that would usually provoke complaints. Noise that once was a source of annoyance and complaint became the "sound of freedom." This heightened sense of patriotism also applied to the U.S. involvement in the War on Terrorism. As U.S. troops took an active role in the War, many citizens were less inclined to complain about military land usage. Moreover, the mass deployments in support of the War on Terrorism led to sharply reduced troop strength at many installations, including Forts Benning and Carson. This, in turn, significantly reduced the frequency with which training and testing could impact surrounding communities. The resulting situation greatly affected the number and frequency of complaints lodged against an installation and created a false sense of satisfaction in combating urban encroachment.

This situation highlighted the criticality of the political climate of an installation and its political relationship with its neighbors for accurate data collection, as well as frequency of complaints. A pro-military public was less likely to complain. However, a public interested first and foremost with their own rights and liberties may likely be at odds with testing and training on installation grounds. It therefore appears advisable to consider sociopolitical factors when conducting research about complaints, especially if used for predictive purposes.

Land-use incompatibilities at Fort Benning

Fort Benning is an undeniable presence in the greater Columbus area. The booming sound of aircraft can be heard throughout the area, while huge billboards interspersed in the areas surrounding the installation thanked the Soldiers for protecting American freedoms and boasted that Fort Benning had the "World's Best Infantry Soldiers" (Greater Columbus Georgia Chamber of Commerce 2005). These sounds and images portray the duality in the relationship between Fort Benning and its surrounding communities. Although their proximity to the fence line presents several problems for the health and well-being of the residents and their property, the community thrives economically, socially, politically, and culturally from the presence of the installation. It is a co-dependent relationship.

According to the complaint records collected from Fort Benning's Environmental Management Division, the majority of the land-use incompatibilities in the Fort Benning area involved noise. Despite this, few official complaints were filed with the installation from 1999 through 2004 (Figure 1.3).



Source: Air/Noise Programs Manager,
Directorate of Public Works, Fort Benning, GA, 2004.

Figure 1.3. Fort Benning noise complaints.

These low numbers suggest Fort Benning did not have severe land-use incompatibilities in terms of noise. However, further research into noise-related issues revealed a much more complex set of issues about the qualitative and quantitative effects that noise had on the surrounding community. For example, the community comments recorded in the EIS for the DMPRC Fort Benning proposed in 2003 exposed a multifaceted set of concerns from people living adjacent to the installation. The EIS also revealed a much more tenuous relationship between urban and military land uses compared to the raw figures of the noise complaints. This was particularly true for residents who made most of the comments, those living near the Hastings Range in the far northeastern corner of the cantonment area.

Given an opportunity to openly discuss issues about Fort Benning training and testing activities, many residents were fairly candid with their opinions regarding their resultant noise and property damage. According to the final EIS, more than 100 people attended the public forums, and many submitted written comments regarding the proposed DMPRC. Further, "concerns regarding noise levels, both existing and future, potentially impacting communities near Fort Benning generated the most comments from the public, resulting in 18 separate comments" (Fort Benning 2004). A closer look at these comments revealed a rich tapestry of problems associated with noise in the Fort Benning area (Table 1.2).

Table 1.2. Selected public comments from Fort Benning EIS for proposed DMPRC.

Relationship revealed through EIS	Comment
Physical effects of noise on property	"Our property is right next to the firing range now. The noise pollution, shaking, and impact is horrible…As it stands, a house cannot be built on our property as planned because the impact would be too damaging to the house. It would break windows and crack the foundation" (Resident of Cols, Attendee of Feb. 18, 2003 public meeting).
	"Noise level to[o] high – shakes house/window now" (Resident of Buena Vista, Attendee, Feb. 20, 2003 public meeting).
	"We have been living next to Ft. Benning for 35 years. We have cracked walls, windows and our fire place from the impact of what is now taking place. We have to deal with fire, smoke and tanks which at times get off course" (Fort Benning area resident, May 4, 2003; comment received via letter).
	"I live within ½ mile of Hastings Range. My house has took a lot of abuse due to firing. The doors do not shut properly, the siding is falling off (Just had new siding installed). Now I need to re-level my house because the foundation is unlevel…I am also concerned about when the control burns come within feet from my home. My home cannot withstand any more abuse" (Resident of Box Springs, Attendee, March 3, 2003 public meeting).
	"I am ½ mile from Hastings Range. My house rattles and shakes now with the firing that is done at Hastings Range. If you build another firing range, this will increase the damage to my home. It shakes my pipes and damages my drain line. I constantly have to repair these" (Resident of Box Springs, Attendee, March 5, 2003 public meeting).
Impact on urban land-scape	"As a resident of Columbus, I would hope that the Army will consider another site some distance away from Columbus and other cities of this size" (Resident of Columbus, Feb. 12, 2003 comment received via letter).
Potential displacement from purchasing of buffer zone lands	"I would support Alternative 3 [an alternative that would move the range south-west of its current location, away from adjacent residential communities]. I am afraid that my family's property will be taken and I would like to know specifics of what is going on – I feel that we are only being given part of the proposal" (Resident of Buena Vista, Attendee, Feb. 20, 2003 public meeting).
Lack of awareness of noise-related issues in area	"When we moved out here, we had no idea that it would affect us this bad. If the noise or vibrations gets worse, we are afraid that our brick and foundation will crack (other houses have already)" (Resident of Box Springs, Attendee, March 5, 2003 public meeting).

The many other related comments from the EIS, in addition to those in Table 1.2, illustrate that land-use incompatibilities from noise (and other disturbances) cannot be measured entirely from complaints lodged with the installation. It was unclear whether any of the residents who provided comments for the DMPRC proposal ever issued a formal complaint with the installation. However, given that only 15 formal noise complaints were filed in 2003, it appears unlikely that all concerned residents formally lodged complaints with the appropriate installation agency.

Community concerns about noise were also demonstrated through coverage by local media outlets. The Columbus newspaper, the *Ledger-Enquirer*, wrote six noise-related articles between February 2003 and March 2004.* One article described the general concern about noise at Fort Benning's Hastings Range:

> To hear nearby residents describe it, it sounds like the lumbering approach of Tyrannosaurus Rex in the movie 'Jurassic Park'…a deep reverberation that shakes the ground, rattles windows and ripples ponds. But it's not some movie-dinosaur stomp that staggers Fort Benning's neighbors. It's gunnery training on the Hastings Range (Chitwood 2003).

The local NBC affiliate, WRBL-TV3, also frequently commented on noise problems. In 2003, in response to numerous telephone calls and e-mails concerning noise in the Fort Benning area, it reported the following story:

> News three has taken several of your calls and emails asking – what's making so much noise and rattling your houses. It's a simple answer—Ft. Benning. But there's actually more to the story….We call it the sound of freedom. We're back and we're training. Ft. Benning is training and retraining its soldiers for war…and you're hearing it all around Columbus…The Army stresses—If you want wins in the battlefield—you have to train at home (Clark 2003).

Noise, however, was not the only source of complaint. Smoke was another concern for residents in the Fort Benning area and revealed another land-use incompatibility between urban and military land uses. Fort Benning practices prescribed burning in many areas of the cantonment area to reduce the risk of forest fire and for local habitat maintenance. As part of this practice, the installation was divided into dozens of units where

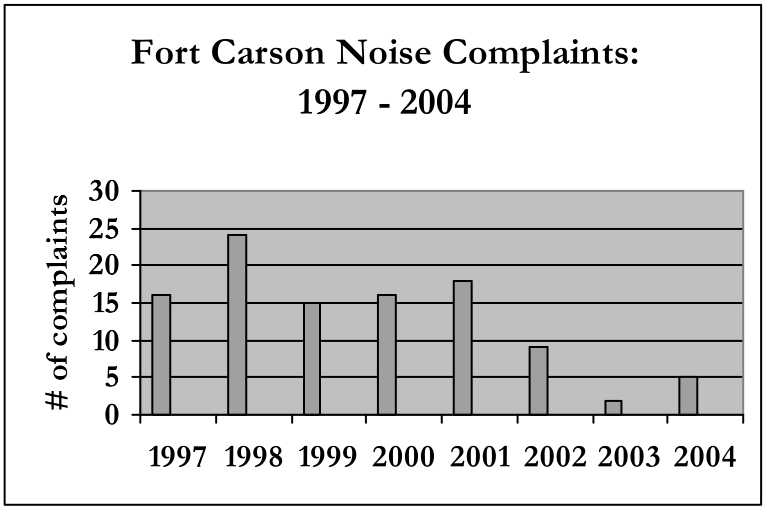
* These articles include: (1) S. Thorne Harper. "Benning Target for Firing Rang," *Columbus Ledger-Enquirer,* February 5, 2003; (2) Tim Chitwood. "Gauging a Range of Noise," *Columbus Ledger-Enquirer,* February 28, 2003; (3) Tim Chitwood. "Hone in on the Range," *Columbus Ledger-Enquirer,* April 7, 2003; (4) Kelly Esters. "Ba-Boom! What Was That? No One's Sure," *Columbus Ledger-Enquirer,* February 20, 2004; (5) Staff reports. "Hearing on Fort Benning Ranges Set," *Columbus Ledger-Enquirer,* March 3, 2004; (6) Harry Franklin. "Post Officials Share Plan for Training Site – Location of $50 Million Digital Range Complex More Remote," *Columbus Ledger-Enquirer,* March 5, 2004.

controlled burning was conducted 75 to 90 days per year, not including weekends and holidays. The nuisance caused by this practice occurred when shifting winds created situations that had negative effects on public health and residential property.

The Environmental Management Division also housed all records received by installation offices from smoke complaints. In 2001, 14 complaints were filed with Fort Benning, while only 3 were filed each year in 2002 and 2004 (Fort Benning 2004). The nature of these complaints varied from problems with breathing to visibility impairment leading to vehicular accidents with fallen trees. Although these data could be used spatially because each complaint was logged with an accompanying address, little supplemental data exist. Several comments from the public meeting for the DMPRC addressed smoke, but only a few of them. Land-use incompatibilities attributed to smoke were considered far less significant than problems with noise by both on-post military personnel and off-post residents.

Land-use incompatibilities at Fort Carson

The area around Fort Carson presented an entirely different set of incompatibilities regarding land use. It also presented an interesting research paradox: the presupposition was made that the communities in the Fort Carson area would have a higher tolerance for the effects of military testing and training. This presupposition was based on the fact that several military installations are in the direct vicinity of Fort Carson, suggesting that the composition of the various communities would be significantly comprised of people working at or stationed at the military installations. Yet, despite these circumstances, Fort Carson had far more registered complaints than did Fort Benning, at least until 2002 (Figure 1.4).



Source: Fort Carson Public Affairs Office.*

Figure 1.4. Fort Carson noise complaints.

The records demonstrated a much more complex land-use incompatibility situation at Fort Carson than depicted by the raw numbers and, at times, revealed a very tenuous relationship between the installation and its neighbors. Among the concerns and issues expressed by community members was the lack of realtor disclosures regarding properties adjacent to Fort Carson, property damage from testing and training practices, emotional and psychological disturbances from Fort Carson activities, the presence of the military in the area, and conflicts from low-flying aircraft (Table 1.3).

It is important to note that, unlike the community comments received from the DMPRC public meetings at Fort Benning, the complaints documented in Figure 1.3 were received and recorded by installation personnel and, thus, were not expressed in the exact words of the complainant. The quotations given in this section of the chapter, therefore, come from the installation complaint record, not directly from the complainant.

* The low numbers following September 11, 2001, may be attributed in part to elevated feelings of-patriotism in support of the Global War on Terrorism and the resulting reluctance to complain about military training activities. However, these low numbers may also indicate an increasingly relaxed system for logging and maintaining complaint records as they were issued. There were an additional three noise complaints for which no year was recorded.

Table 1.3. Selected noise-related complaints for Fort Carson.

Nature of Complaint	Comment
Concern about property damaged resulting from testing and training	The…"noise and vibration level [are] constantly tiresome throughout the year" and the "vibration and noise [have been] causing shaking of house and possible cracking of foundation" (Resident of Fountain, March 4, 1998).
	"A series of blasts…[have] been shaking [his] house, rattling windows, [and] causing cracks in [the] ground," causing him to have to repair his driveway (Resident of Fountain, March 9, 2000.
	Fort Carson noise was– "shaking [the] house" and creating "cracks in driveway and sidewalks" (Resident of Fountain, January 13, 2000).
	"Pictures falling off the walls in her house" and her baby waking from noise "vibrating the house" (Resident of Fountain, November 29, 2000).
Mental, emotional, and psychological disturbances from testing and training	Fountain resident claimed that both her dog and her young child were frightened of the "very loud shooting noises" from Fort Carson. She explained that she and her child had "just moved to CO and are renting this place while looking to buy; [and that she] just want[ed] to get a number to call to get [a] firing schedule so [she] can tranquilize dog and prep. kid" (Resident of Fountain, April 2,1998).
	Complainant described how the "loud 'booms'" from Fort Carson make her feel "like she is going to have a nervous breakdown [because] the noise is so loud and continuous" (Resident of Penrose, March 24, 1999).
	"All-night bombing noise keeping up [the] entire family" (Fort Carson area resident, June 8, 2001).
Lack of awareness of noise-related issues in area	One complainant was "very upset because he just purchased a half-million dollar home and is thinking he must leave. He wanted to know about the extent of training" (Resident of Colorado Springs, March 6, 2000).
	Another complainant stated that he "wants noise [from Fort Carson] to stop. This was their dream – now their problem is with Ft. Carson. [He] bought property from Andy King [of the] Foothills Land and Loan, [but the] realtor did not disclose the location near Ft. Carson" (Resident of Pueblo, August 13, 2001).
General concern of presence of Fort Carson in the area	One complainant was "upset about on-going training [and] wants to know when it will cease. [He was also] curious as to whether it will halt when soldiers deploy [and] wonders why Army builds up around communities" (Resident of Pueblo West, January 26, 2000).
	Another complainant from Pueblo West stated via a letter that "we live in the largest growing city in Colorado, and most bombing is done a few miles from our boundary at south end of Fort Carson. They need to move this to bother someone else. These operations cannot continue in the middle of urban areas. The military from Ft Carson to DOD have been very stubborn about being a big nuisance" (Resident of Pueblo West, March 26, 2000).
Low-flying aircraft creating noise and other problems	Complaints from low-flying aircraft were common within the complaint records from Fort Carson. In one situation, the Mayor of Woodland Park reported that a "helicopter flew [through a] residential area low enough for [the] crew to be observed and [the aircraft also] shook the foundation of the house and window" (Resident of Woodland Park, December 30, 2001).
	Another complainant reported that she witnessed "helicopters flying extremely low over [her] house, scaring cattle". She also noted that she "could see [the] pilot from [her] couch" (Resident of Yoder, January 16, 2002).
	One complainant described feeling "targeted" by low-flying aircraft (Resident of Buena Vista, January 17, 2002).
	Another resident described how low-flying helicopters scared his livestock and his grandchildren (Fort Carson area resident, July 27, 2001).

Source: Fort Carson Public Affairs Office. All quotes extracted from Fort Carson complaint record.

The noise-related records indicated the growing land-use incompatibilities in the Fort Carson area resulting from urban growth. More importantly, they highlighted how increased urban growth can disrupt the economic relationship that is, perhaps, the most significant facilitator for mitigating land-use incompatibilities between military installations and neighboring communities. Traditionally, military installations have been the main economic force in their areas, and as such, *supporting* communities tend to be more willing to tolerate the negative impacts in exchange for the economic benefits. However, population growth typically correlates to growth in business and industry, turning *supporting* communities into *surrounding* communities. The result is not only the dilution of the military's economic presence in the area, but also the lowering of an area's tolerance level for the negative effects generated by the installation. The data compiled in the complaint record database for Fort Carson suggested this was, indeed, the process occurring in the Colorado Springs area. As the records indicated, the general presence of the military in this area was, despite its economic benefits, not always welcomed.

In addition to noise, fire was the other dominant source of complaint in the Fort Carson area. Unlike Fort Benning, complaints resulting from fire at Fort Carson occurred with enough frequency to warrant further investigation. Despite Fort Carson's location in the arid southwest, with its increased potential for wildfires compared to other installations, operations continue even during the height of wildfire season. Hence, most complaints involved the perceived threat to local homeowners of continued testing and training during times of wildfire warnings. As one person stated, "Firing artillery causes fires when the weather is dry and hot [and the] complainant feels this is unsafe to homeowners" (Fort Carson 2004). In early June 2002, when the risk of wildfire was high, seven complaints were received by residents who felt it "irresponsible to [use live weapons] during time of high fire risk" and "that Fort Carson should be doing dry fire training in order to avoid fires and keep them from spreading" (Fort Carson 2004). Even though these complaints occurred during periods of dangerous wildfire conditions, they reflected an ongoing land-use incompatibility between residential communities and military testing and training practices.

Overall, the complaint record databases constructed for both Fort Benning and Fort Carson reflected multiple land-use incompatibilities with the surrounding communities, particularly related to noise and smoke. Despite the inconsistencies in the quality and format of data captured from both installations, the records provided extensive information about the underlying causes for complaints resulting from encroachment. The next step is to determine whether or not, and to what extent, demographic analysis can reveal any underlying socio-economic trends that may be used in predictive modeling to determine where land-use incompatibilities are more likely to occur.

Spatially expressing the database

The most obvious and meaningful way of spatially expressing the complaint record database is with GIS. GIS mapping allows for simultaneous viewing of census indicators with complaint locations to determine the presence and extent of any socio-economic trends. As such, preliminary maps were generated as examples of the spatial expression possible. As the databases compiled for Forts Benning and Carson offered varying degrees of success regarding their ability to be mapped, only Fort Benning was selected to offer examples of the kind of maps possible with these data.* In order to predict and mitigate land-use incompatibilities, researchers must determine in what areas people are likely to complain, and whether or not the likelihood for complaint is correlated to socio-economic factors. Due to time and funding constraints, only a limited set of demographic indicators were analyzed against the complaint record database. As such, primary interest focused on the relationship between complaints and income, education level, and whether or not those who complain have children. The resulting maps all used the Fort Benning Noise Complaint Map originally produced by Fort Benning as the main map layer. This base map reflected all official noise complaints recorded between January 2000 and February 2003, as well as the complaints recorded in the DMPRC public comments, for a total of 43 data points. Demographic data layers were added to this base map using 2000 federal census data for the three indicators: average household income, percentage of people with a bachelor's degree or higher, and percentage of people under the age of 5 (Figure 1.5, Figure 1.6, and Figure 1.7).

* As noted above, Fort Benning's complaint database offered a much more robust quantitative content due to the diligence in record-keeping practiced by the Fort Benning staff. The Fort Carson data set provided additional obstacles to the kinds of spatialized projects that would be possible for these data, and was therefore excluded from this portion of the study. With additional funding and time, the Fort Carson data could be spatially expressed and mapped as well.

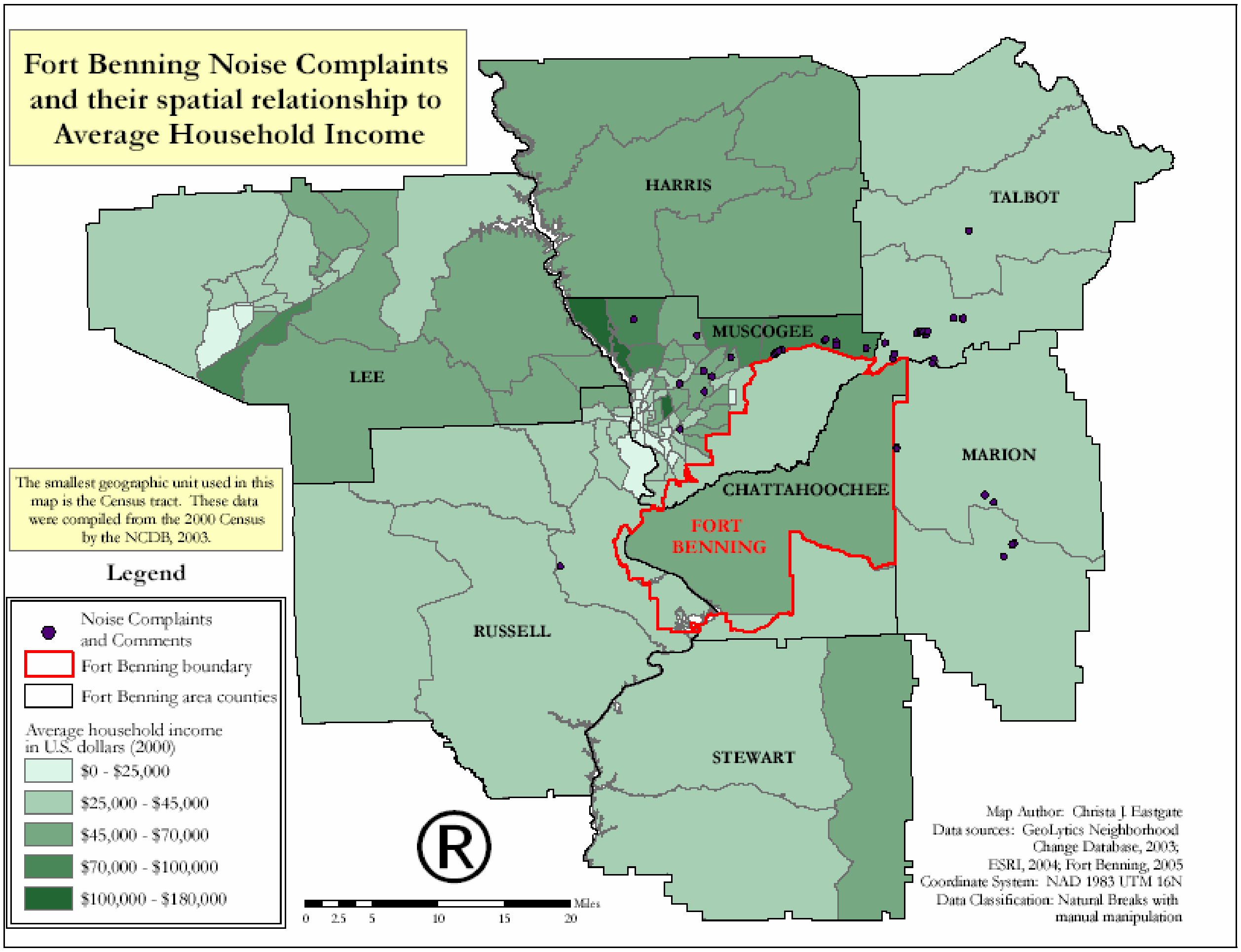


Figure 1.5. Fort Benning noise complaints and their spatial relationship to average household income.

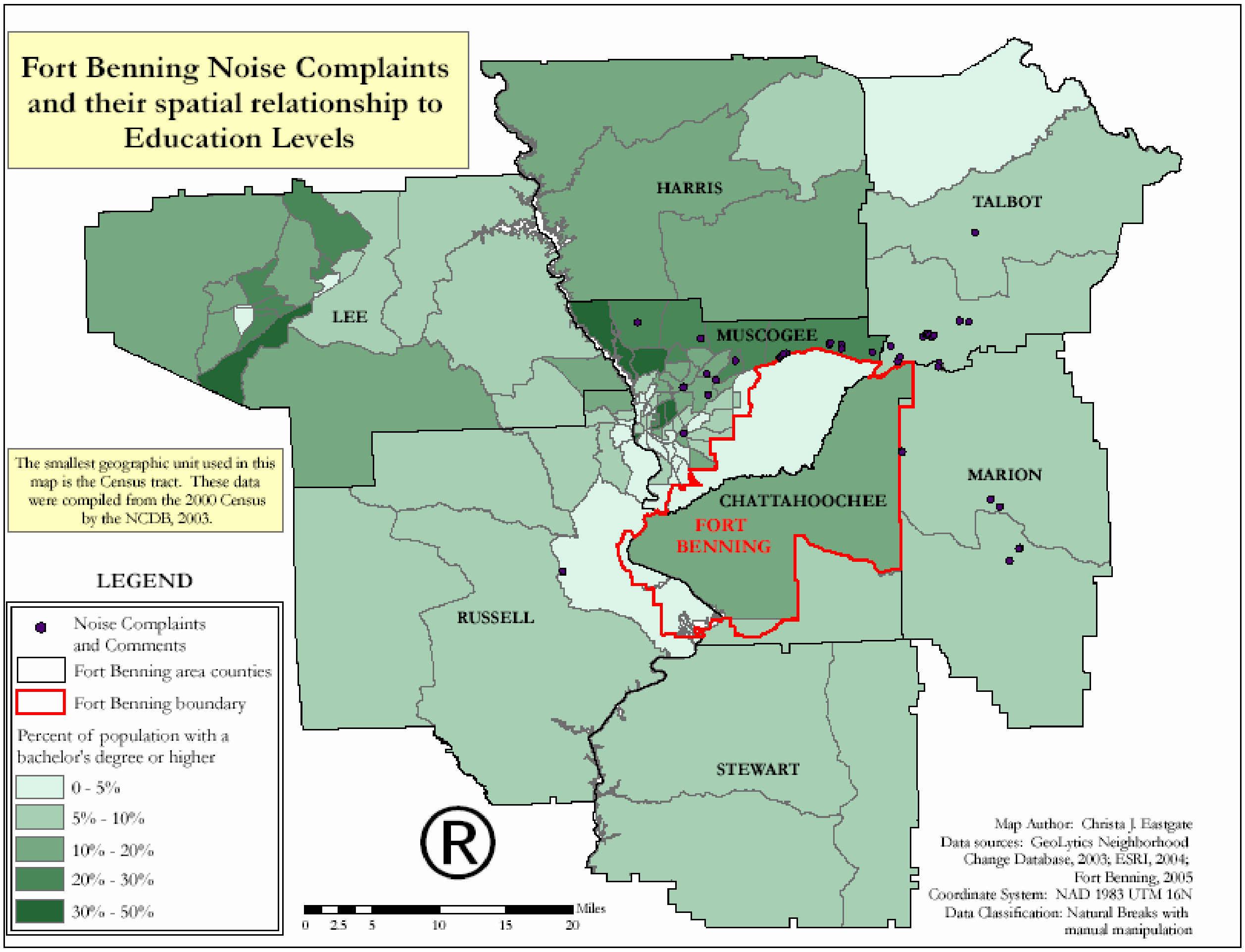


Figure 1.6. Fort Benning noise complaints and their spatial relationship to educational levels.

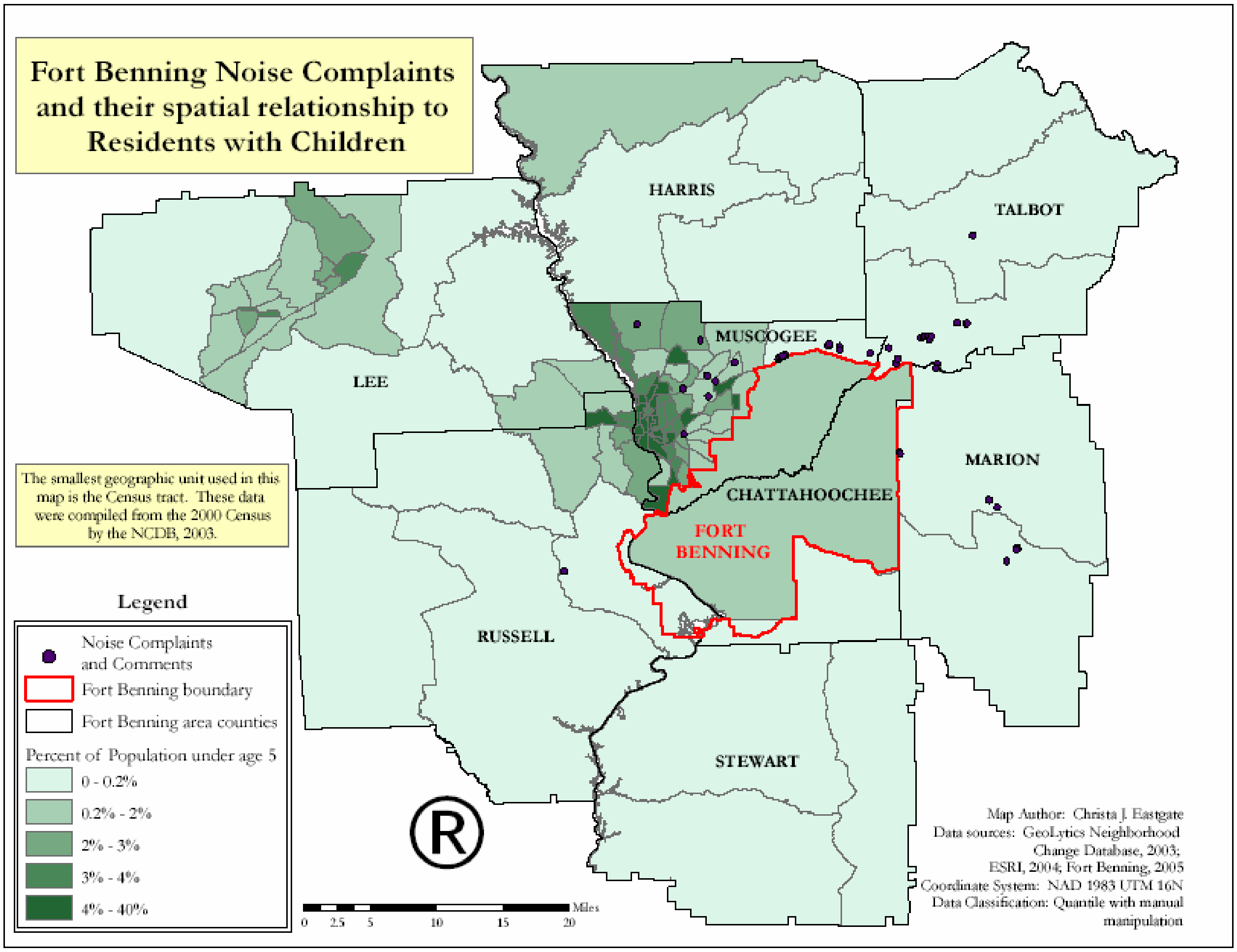


Figure 1.7. Fort Benning noise complaints and their spatial relationship to residents with children.

These maps indicate several things. The least surprising result is that the likelihood for complaint increases with proximity to the installation boundary. Of the 43 data points displayed on the map, 81% of complaints were from people residing within approximately 5 miles of the fence line (Table 1.4). These maps also indicate that 79% of the complaints were from households with less than 0.2% of the population under age 5; 63% were from households with average annual earnings between $25,000 and $45,000; and 56% of complaints were from households where 10% or less of the population had a bachelors degree or higher (Table 1.4). In short, these maps suggest that residents without young children, who are middle class and above, and who do not possess higher education levels are more likely to complain.

Table 1.4. Analysis of Fort Benning data points.

Proximity			*Children*		
Distance to Fence Line	No. of Data Points	% of Complaints	% of Pop Under Age 5	No. of Data Points	% of Complaints
< 1 mile	15	35%	0-0.2%	34	*79%*
1 – 5 miles	20	46%	0.2%-2%	3	*7%*
5 > miles	8	19%	2%-3%	5	*12%*
			3%-4%	0	–
			4%-40%	1	*2%*
Income			*Education*		
Ave Household Income	No. of Data Points	% of Complaints	% Pop with BA/BS Degree or Higher	No. of Data Points	% of Complaints
$0-$25k	0	–	0-5%	1	*2%*
$25k-$45k	27	63%	5%-10%	23	*54%*
$45k-70k	5	12%	10%-20%	6	*14%*
$70k-$100k	11	25%	20%-30%	13	*30%*
$100k-$180k	*0*	–	*30%-50%*	*0*	–

Conversely, and of particular interest, residents whose average household income puts them within or slightly above the poverty level filed no official noise complaints (Table 1.4). However, these observations are not intended as definitive conclusions about the relationship between residents and military testing and training operations. Instead, they are merely examples of the kinds of mapping and other spatial analytical projects these data may support. Rather than offering concrete conclusions about socioeconomic indicators, these maps, based on limited analysis, highlight the need for further investigation.

Findings and conclusions

Additional quantitative and qualitative methods should be performed to supplement this research, such as additional demographic and location quotient analysis of communities adjacent to military lands. The current research suggests people most prone to complaining about military training activities will fit the following profile: employed by a company other than the U.S. Army, live within close proximity to the installation, have recently moved to the area, and/or have no close friends or relatives employed by the installation. It is hypothesized that people who do not have a social, cultural, economic, or political relationship with an Army installation will be more likely to issue complaints about on-post training and testing practices. Determining the location(s) of these at-risk groups may be a judicious way to focus anti-encroachment efforts. Simple demographic indicators may be used in such an analysis with basic GIS methods.

Similarly, location quotient analysis can be used to determine the proportion of people in a given area who are employed by a particular industry. In this case, it may be helpful to determine the proportion of people in the surrounding communities employed by Fort Benning to determine if there is a spatial clustering of these military personnel in the greater area. It will then be possible to determine what areas are less influenced by military activity and are, therefore, more prone to complaining about land-use incompatibilities. This analysis would be beneficial in identifying the demographic construction of communities that are more sensitive to the testing and training practices on installations.

A variety of spatial statistics and quantitative geographic methods, common within geographic discourse, could enhance this research effort. For example, simple univariate regression or logistic regression could be used to understand the relationship between socioeconomic factors and complaints. In addition, spatial autocorrelation could help determine if complaints in one area influence complaints in another area.

An analysis of the changing demographic dynamics of the population may also prove useful. Such analysis would look broadly at how the community has changed over time and how such changes may be reflected in the population's reactions to encroachment. It may also be useful to determine if the number of complaints in a given area has a positive relationship with lower socioeconomic status indicators. Specifically, this research suggests that those segments of the population that feel socially, politically, or particularly economically unempowered may be less likely, if at all, to file a formal complaint. This was indicated by the findings shown in Table 1.4 wherein residents with a lower socioeconomic status filed no official noise complaints. Speculative reasons explaining this statistic include: marginalized groups may feel complaining would not do any good, they may be unsure or unaware of how and to whom to complain, they may have misperceptions about the time and energy needed to file a complaint, and/or training noise may be the least of the concerns and annoyances they face and contend with on a regular basis. As such, it is hypothesized that the less power a population has economically, socially, and politically, the fewer complaints will be lodged due to military activity.

Finally, this research has shown that the data gathering process involved in creating a complaint record database of land-use incompatibilities is far more complex and challenging than simply collecting files and digital documents. Topics as emotionally charged as property damage from noise and health risks from smoke and noise manifest themselves in multiple, sometimes competing, ways. Further, it is apparent that the perceived level of land-use incompatibilities shifts with changing political and cultural climates. In times of war and heightened patriotism, land-use incompatibilities seem to take a back seat to the support of troops and training operations. This must be taken into consideration when complaint records are used to monitor and measure land-use incompatibilities. Records must be taken at regular intervals, in times of war and peace, to understand how these records change according to the political climate of the country. Although the Army may never completely solve land-use incompatibilities, with the combined efforts of community participants and effective predictive-based planning, the problem can be, if not avoided, certainly mitigated.

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2 Identifying Where Dust- and Smoke-Generating Training and Testing Activities Will Be Allowed

Michael Kemme and James Westervelt

Introduction

Development of civilian activities, especially residential areas, around military installations is threatening the sustainability of traditional military land uses associated with training and testing ranges. (Lacey 2001) Urban development is increasing the potential for complaint and environmental regulatory action due to emissions of particulate matter (PM) from the ranges. Large amounts of dust can be generated from wheeled and tracked vehicle maneuvering, rotary and fixed wing takeoffs and landings, and artillery back blast. The large soil-based PM emissions can create legal, regulatory, ecological, and practical problems for military training and testing installations. The emissions can limit or restrict time, frequency, and location of training; close ranges; or completely shut down training exercises due to the Clean Air Act Amendment of 1990 or threatened and endangered species compliance requirements (Kemme et al. 2001). These problems will worsen not only due to urban development but with mission realignments; the deployment of new weapon systems; and the use of training spaces for larger, multiservice operations.

The U.S. Environmental Protection Agency (U.S. EPA) has set National Ambient Air Quality Standards (NAAQS) for PM. Annual and 24-hour standards are set for PM10 (PM less than 10 μm in aerodynamic diameter) and PM2.5 (PM less than 2.5 μm in aerodynamic diameter). The standards for PM are based on measured health effects of populations exposed to PM. These health effects include short-term exposure symptoms such as cardiovascular events, asthma attacks, coughing, chest discomfort, wheezing, shortness of breath, and unusual fatigue. Health effects from longer term exposure include reduced lung function, the development of chronic bronchitis, and premature death (U.S. EPA 2004). In addition to the health effects described above, complaints from PM emissions include soiling of surfaces, reduced visibility, and negative impacts on vegetative growth and development. PM10 is more representative for dust emissions since dust contains much more PM10 than PM2.5 on a mass basis.

The soil-based PM emissions associated with training and testing activities are known as fugitive dust since it is not emitted from a confined gas flow, such as from a stack. In general, regulators have dealt with fugitive dust emissions as a nuisance-type source and have taken action only when citizens complain about the emissions. However, regulators can also become involved when significant new fugitive dust sources are scheduled to appear on training and testing ranges because of new missions. Because of General Conformity and New Source Review regulations, new fugitive dust emissions must be estimated in certain cases, and PM10 emissions must be reduced if certain thresholds are met. Several Army training installations have experienced reductions in training capacity because of regulatory actions associated with fugitive dust emissions.

Part of the challenge for military installations is the inability to accurately estimate the mass emissions of PM from training and testing sources. These military-unique sources have either only recently been characterized or the scope of their PM emissions are unknown. A recent study has proposed PM10 emission factor estimates for U.S. Army wheeled vehicles (Gillies et al. 2005). Figure 2.1 is taken from this study and shows the relationship developed between vehicle distances traveled, vehicle mass, vehicle speed, and PM10 emissions. Work is ongoing to develop PM emission estimation techniques for tracked vehicles, fixed and rotary wing aircraft takeoffs and landings, and artillery back blast (Kim et al. 2005). Research on military installations is also occurring to develop a model to predict the amount of PM reduction that occurs from vegetative capture (Cowherd et al. 2005).

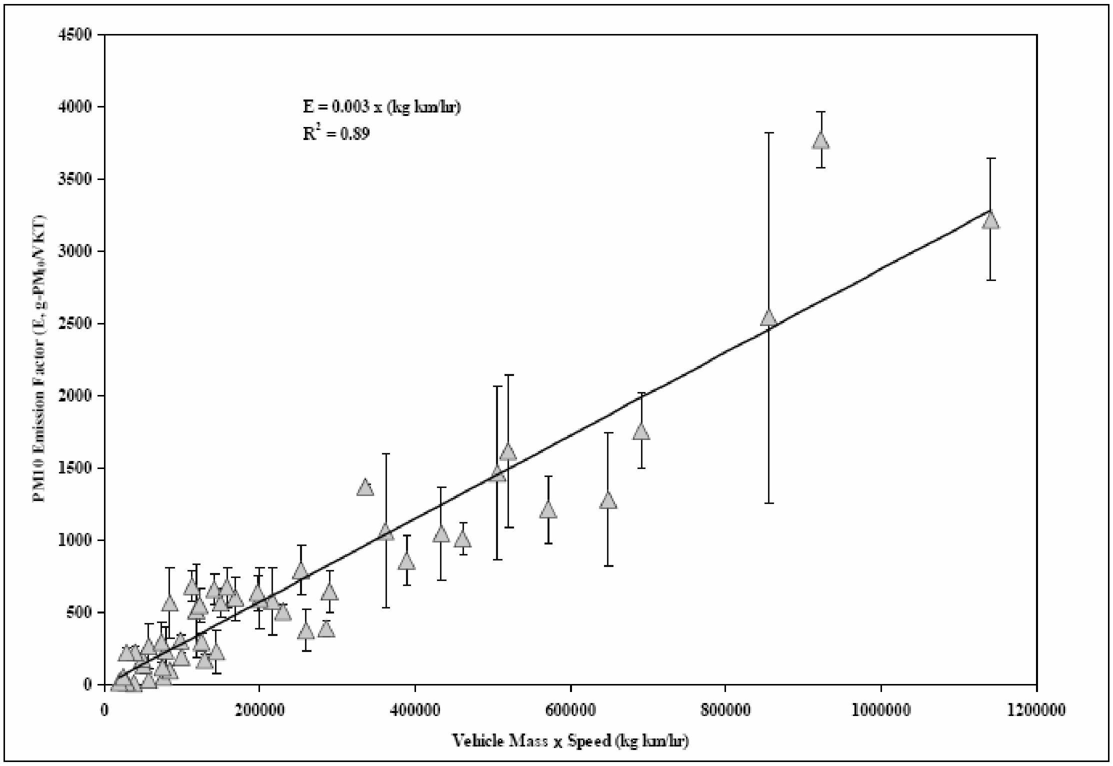

Figure 2.1. Vehicle emissions of dust characterized as a function of the product of vehicle speed and mass.

An understanding of the PM10 emissions from training and testing events is only the first step in understanding PM10 emission impacts on the surrounding communities. Range designers and operational decision makers also must have an understanding of how these emissions are transported and dispersed across the installation boundaries. Air dispersion models are used to predict concentrations of air pollutants downwind of a pollution source. These models are commonly used to predict air pollution impacts from a well-defined source on an existing community. However, it is difficult to apply complex air dispersion models to determine air pollution affects from many potential range sites and uses while taking into account future land-use growth around the installation. The alternate concept proposed here is to use the basic concepts of dispersion modeling but to take the perspective of the population's tolerance to fugitive dust emission exposure and to couple the model with a geographical information system (GIS) tool that predicts future civilian land use.

Approach

The goal of this work is to formulate a quick approach to identifying suitable areas for PM emission generating military training within a landscape containing actual or predicted urban patterns. The available inputs to the analysis will be a GIS-based map of residential locations, general local land cover, and average wind speeds. In this analysis, the locations of receptors (in this case, residential areas) are known. The map to be developed will show the probability of complaint from individuals in those residential areas in response to PM emission generating training occurring anywhere in the region of interest.

The analysis begins with equations that generate downwind concentration patterns when the source is known. The most common way of modeling the dispersion of pollutants downwind from a source and predicting the ambient concentration of the pollutants is called Gaussian dispersion modeling. Figure 2.2 shows the coordinate system used for this model. The origin of the coordinate system is at ground level below the release point of the pollutant. The x axis is oriented in the direction of the wind flow, the y axis is oriented in the crosswind direction, and the z axis is oriented in the vertical direction. This coordinate system is assumed to exist for the averaging time used for estimating air pollutant concentrations.

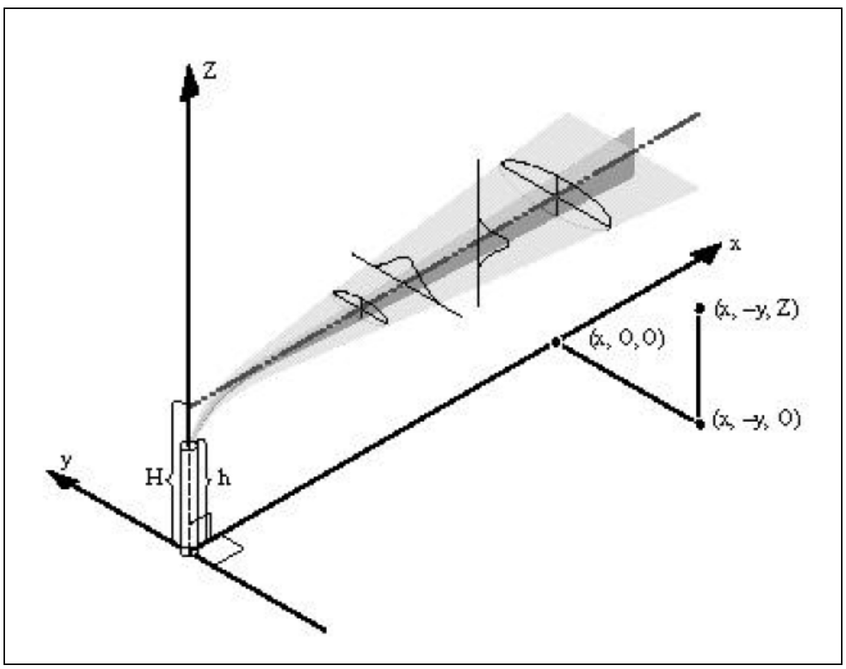

Figure 2.2. Coordinate system for the Gaussian plume dispersion model (Turner 1994).

Gaussian plume dispersion models assume a normal distribution of pollutant concentrations in the vertical "z" direction and the horizontal "y" direction. The standard deviations of the distributions σ_z and σ_y increase as the pollutants move downwind and these standard deviations are also functions of the stability of the atmosphere. The standard deviation σ_z and σ_y are also commonly referred to as the dispersion coefficients. In the x direction (direction of the wind), there is no assumed dispersion but the pollutants are assumed to move at the same speed as the wind and greater wind speeds will result in greater dilution of pollutants.

For rural conditions, Pasquill stability categories are a common way of indicating the turbulence in the atmosphere primarily due to the upwelling of air heated at ground level. In this system, stability category A is the most turbulent, occurring on days with low wind and high insolation, and stability category F is the most stable. As mentioned above, the stability of the atmosphere is an important factor in estimating the dispersion coefficients that describe the distribution of pollutants in the atmosphere. The stability category can be predicted by the time of day, wind speed, and solar insolation as shown in Table 2.1.

Table 2.1. Key to the Pasquill Stability Categories (Pasquill 1961).

Surface wind speed (m/s)	Daytime insolation			Nighttime cloud cover	
	Strong	Moderate	Slight	Thinly overcast or ≥ 4/8 low clouds	≤ 3/8
< 2	A	A – B	B	-	-
2 – 3	A – B	B	C	E	F
3 – 5	B	B - C	C	D	E
5 – 6	C	C – D	D	D	D
> 6	C	D	D	D	D

Equation 2.1 is the basic Gaussian dispersion equation. Care must be taken to use consistent units so that all terms remain dimensionally correct. The equation accounts for the affects of the emission rate, the dilution from the wind, the spread of the plume in the vertical and crosswind direction as it travels downwind, and reflection of the plume from the ground:

$$C(x,y,z;H) = \frac{Q}{2\pi u \sigma_y \sigma_z} e^{\left(-\frac{y^2}{2\sigma_y^2}\right)} \left[e^{-\left(\frac{(H-z)^2}{2\sigma_z^2}\right)} + e^{-\left(\frac{(H+z)^2}{2\sigma_z^2}\right)} \right] \quad \text{(Eq 2.1)}$$

where:

C(x,y,z;H)	=	contaminant concentration at the receptor
Y	=	distance of receptor from the center of the plume perpendicular to the plume movement
Z	=	distance of receptor above the ground
Q	=	contaminant mass emission rate
σ_y	=	lateral dispersion coefficient
σ_z	=	vertical dispersion coefficient
u	=	wind velocity in the downwind direction
H	=	height of release.

A majority of the PM emitted during training and testing activities is released just off the ground. Examples of this are dust emissions from tracked and wheeled vehicles and obscurants. If an assumption is made that PM is released at the same height as receptors and that the wind is blowing directly toward the receptor, then the Gaussian dispersion equation can be simplified as shown in Equation 2.2:

$$C(x,0,H,H) = \frac{Q}{2\pi u \sigma_y \sigma_z}\left[1 + e^{-\left(\frac{2H^2}{(\sigma_z)^2}\right)}\right] \quad \text{(Eq 2.2)}$$

If the height of release is assumed to be 1.5 m, then the equation becomes:

$$C(x,0,1.5,1.5) = \frac{Q}{2\pi u \sigma_y \sigma_z}\left[1 + e^{-\left(\frac{4.5}{(\sigma_z)^2}\right)}\right] \quad \text{(Eq 2.3)}$$

A common way of estimating σ_z and σ_y for rural conditions is a combination of the work of Pasquill and Gifford and the values are commonly called the Pasquill-Gifford dispersion coefficients (Gifford 1960; Pasquill 1961). Equations for estimating Pasquill-Gifford dispersion coefficients were developed that depended on the Pasquill stability category and distance downwind. If stability category C is assumed as the most common daytime stability category, the rural dispersion coefficient equations become:

$$\sigma_y = 1000x\tan(12.5 - 1.0857\ln(x))/2.15$$

$$\sigma_z = 61.141x^{0.91465}$$

where x is measured in kilometers.

In urban environments, a different set of dispersion coefficients are used. The dispersion coefficients will vary greatly for different stability categories. The selection of only the C stability category is a simplification and reflects an average of the atmosphere's stability over the course of a year. If the Pasquill-Gifford equations are substituted into Equation 2.4, the Gaussian plume dispersion equation can be expressed as:

$$C(x,0,1.5,1.5) = \frac{Q}{\pi u 0.056876x^{1.91465}\tan(12.5 - 1.0857\ln(x))}\left[1 + e^{-\left(\frac{1}{830.72x^{1.8293}}\right)}\right] \qquad \text{(Eq 2.4)}$$

The only inputs required for this equation are wind speed (m/s), source emission rate (g/s), and distance downwind to the receptor (km). The pollutant concentration *C(x,0,1.5,1.5)* will have units of $\mu g/m^3$. Since this equation assumes a stability category of C, it should not be used if the wind speed is less than 2 m/s. Stability category C never exists with winds that low.

In addition to the assumptions mentioned above regarding release height, Pasquill stability category, and limited wind speed range, Equation 2.4 does not consider other factors found in more robust Gaussian dispersion model software. Some of these excluded factors are the atmospheric boundary layer that can limit the mixing height of the atmosphere, wet and dry deposition of PM, terrain effects on the plume and wind field, area and line sources of PM, and the background concentration of PM. The intent of this research is to provide a relatively simple screening level concentration estimate that can be applied to all receptor grids in a GIS representation of areas surrounding an installation and coupled to a model that predicts future long range land growth patterns surrounding military installations. A general description of this approach is described in a recent report (Westervelt 2004).

Figure 2.3 illustrates a plot of PM10 concentration with distance downwind for a wind speed of 4 m/s and an emission rate of 10 g/s. The figure shows the rate of PM10 concentration decline is much greater near the source than it is further away from the source. Therefore, the plume becomes more homogeneous as it travels downwind.

The calculated concentration can be associated with a probability of complaint by using the NAAQS for PM10 (National Ambient Air Quality Standards for particulate matter less than 10 micrometers in diameter). The PM10 NAAQS are 150 μg/m³ for the 24 hour standard and 50 μg/m³ for the annual standard. The shorter term 24 hour standard is more appropriate for complaint probability purposes since it is measured over the shorter time period when complaints occur. Since the NAAQS are set to protect the public health of sensitive populations, there is a good probability that 100% of receptors would complain with a predicted PM10 concentration level at or above 150 μg/m³. For the first version of this analytical approach, it is assumed the complaint probability is zero at 0 μg/m³ and increases linearly up to 150 μg/m³. Therefore, the percent probability of complaint calculated from the estimated concentration of PM10 (C) is shown in Equation 2.4:

$$P = \frac{C}{1.5} \quad \text{(Eq 2.4)}$$

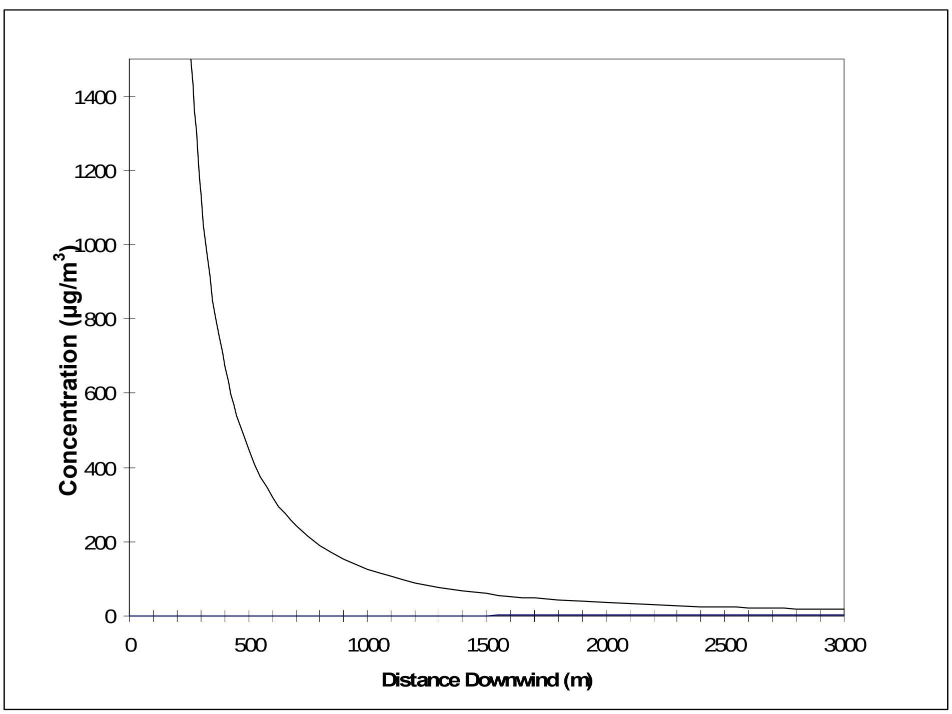

Figure 2.3. PM10 concentration at plume centerline downwind of source.

Since the concentration equation assumes the wind is blowing directly at the receptor, the probability of complaint is calculated only when the wind blows in the direction of the receptor. Figure 2.4 shows how the probability of complaint changes with distance downwind from the source. This example also assumes a wind speed of 4 m/s and a PM10 emission rate of 10 g/s. Because the probability of complaint was assumed to be linearly related to the estimated PM10 concentration, Figure 2.4 correlates to Figure 2.3 in showing the same rapid rate change near the source compared with distances farther downwind.

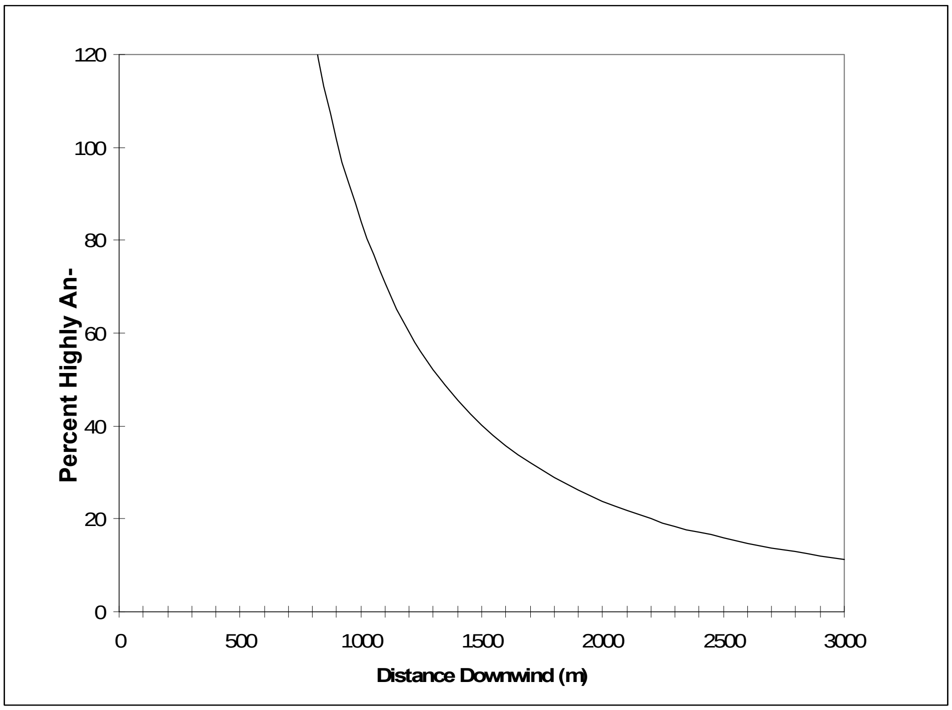

Figure 2.4. Percent highly annoyed at plume centerline downwind of source.

Implementation

The above methodology has been implemented as a program called r.dust within the Geographic Resource Analysis Support System (GRASS) (Goran 1989) running on a Linux computer. The r.dust program offers the following command-line arguments:

input	mMap file with integer number of receptor at each location
output	name of raster map file to contain results
ws	assumed wind speed (m/s)
EmissRate	PM10 emission rate (g/s)

The input raster map provides the downwind distances required by the Gaussian plume dispersion equation. Each location with residents is used to calculate an output image showing the change in annoyance probability with distance away from the receptor(s). At individual locations, the probabilities for each resident are multiplied to calculate the total probability for all receptors residing at that location. After probability decay images are created for all locations, they are added together to create an image representing the probability of complaint for all receptors found in the input map file.

To obtain results for future scenarios with increased encroachment around the installation, the program r.dust can be run with the input map containing predictions of future land-use patterns. By comparing results of the two r.dust runs, training and testing decision makers can visualize anticipated changes of the best locations for avoiding complaints from testing and training PM emissions.

Discussion

This research resulted in the development of a tool to help land planners minimize future complaints due to PM emissions from training and testing activities. The approach provides a way for military planners to visualize the degree of annoyance that can be attributed to new training and testing activities or increases in encroachment. Minimizing annoyance will reduce the potential for regulatory scrutiny since most regulatory actions dealing with fugitive dust emissions originate from a citizen's complaint. The objective of this work is to provide an aid for sustaining the training and testing mission and capacity of military lands during times when encroachment and changes to military mission and land use threaten this capability.

An enhanced version of the r.dust software may be developed with the capability to accept location-specific information about distributions of wind speed/direction, distributions of atmospheric stability classifications, consideration of background PM concentrations, and treatment of vegetative removal of PM emissions. In addition, the methodology will be improved by attempting to gain a better understanding of the relationship between PM concentrations and level of annoyance. This tool will become part of a suite of tools that consider other encroachment issues such as noise, light, and radio frequency emissions from training and testing activities.

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3 Identifying Where Noise-Generating Training and Testing Activities Will Be Allowed

James Westervelt and Michael J. White

Introduction

The generation of noise, dust, smoke, light, and radio signals from a land use such as military training areas, airports, and factories can be incompatible with nearby residential areas (Schomer et al. 1995). Most military installations were originally located in remote areas on land that was not valuable to cities and often unsuitable or marginal for agriculture (Deal et al. 2002). Typically, property (or a subset of property rights) was purchased or acquired, creating a dejure ownership, and a fence line demarked the apparent edge of the property. Military training and testing could then be conducted within the installation boundaries while owners of areas outside the property boundary continued activities such as farming, grazing, and forest harvesting. Dust, smoke, noise, and radio signals generated by the military training, however, crossed the property boundary into neighboring lands (Figure 3.1). The nature of the use of the neighboring land was originally fully compatible with these impacts and, over time, a de facto ownership of the right to generate these impacts was established (Lacey 2001).

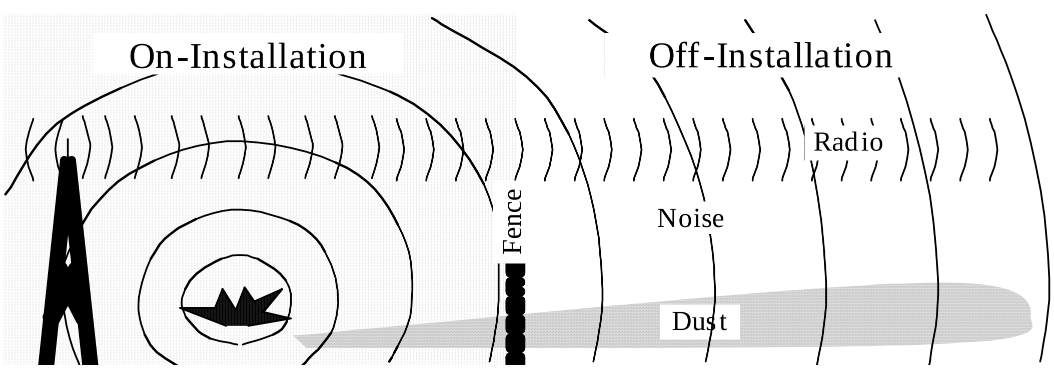

Figure 3.1. Potential incompatible land-use annoyances.

Establishment of the de facto rights must be made by demonstrating a historic use. In recent decades, establishing this history has been supported through the use of spatially explicit simulation and land analysis software.

For example, historic noise footprints can be created with software such as BNOISE (Little 1981) and SARNAM (Pater et al. 1999) that identify noise levels across the landscape associated with recorded weapon firings and munitions impacts. Air dispersion models can also be used to identify historic off-installation smoke and dust concentrations associated with recorded training exercises and weapon testing (Aerospace Corporation 1997). The signal strength of radio broadcasts across the landscape can also be modeled based on frequency, transmission strength, atmospheric conditions, land form, and land cover (Ralston et al. 1998). Such models are also extremely useful for predicting the impact of proposed new training and testing ranges on neighboring land and neighbors (Franklin 1980).

The long-term viability of proposed new training and testing ranges must be made with respect to the impacts of future as well as current neighbors. Although there may currently be no residential neighborhoods in areas impacted by a proposed firing range, the development of such neighborhoods in the future may significantly decrease the long-term cost effectiveness of the range construction. De facto ownership can be problematic to establish and may be insufficient to prevent future developments. Instead, the Department of Defense (DoD) can use various authorities to purchase land outright or to purchase property development rights that will prevent future developments, thereby ensuring the long-term viability of a new range.

The long-term viability and sustainability of a military installation and its associated training and testing areas is based not only on its ability to sustain a current mission, but to accommodate future unknown missions. Recently, the DoD completed a fifth Base Realignment and Closure (BRAC) analysis (DoD 2005) that will result in the re-stationing of many troops, soldiers, and airmen. Installations were analyzed with respect to their long-term ability to accommodate missions. Those installations facing significant nearby urban growth now and in the future must be viewed as less able to sustain military training and testing because of (1) the probability of increased complaints from residential areas, and (2) the inability to expand the training and testing ranges into adjoining areas. As a result of each BRAC exercise, the training and testing mission at installations can significantly change both in the level of training throughput and the type of training. Therefore, in planning for the long-term viability of military installations and the economic base they provide to their supporting communities, installations and communities must consider the need to support current missions and prepare for and attract future missions. For example, an installation currently supporting infantry training may want to keep open its potential for supporting noisier artillery training. An airbase with runways to support fighter aircraft may want to keep open its opportunity to extend runways to accommodate heavier aircraft in the future.

While analysis tools to predict the impact of actual or planned training or testing are readily available, they provide inadequate support for analyzing installation suitability for future unknown activities. They are good at answering the question, “If a training range is placed here, what is the pattern of the impact on the surrounding area?” They are not as useful for answering the question “Where can I consider placing a training range?” Instead of running an analysis of the impact of an actual or planned activity, we need to analyze the impact of regional residential areas with respect to the collective tolerance of the residents to an activity that needs to be placed in the region.

Approach

One of the most important factors to consider when supporting military training is noise. Let us therefore consider the requirement to identify where, across a landscape, a noise-producing activity could be located to minimize the potential of complaint from receptors. Suppose we know that annoyance depends on the received noise level and that the locations of receptors are known or given. Consider first a single receptor; perhaps a single-family residential house. As an example, let us assume the activity of concern requires the use of an electrical generator that is known to produce a sound pressure level equal to 110 decibels (dB) at 200 meters distance.

Sound power dissipates equally in all directions from a nondirectional source. For such a source located near to the ground, sound power is spread evenly across hemispheres of increasing radius centered on the source. The sound intensity (sound power crossing unit area) will decrease as the surface area increases, according to an *inverse-square law*:

$$I = I_1 \left(r_1^2 / r^2 \right) \quad \text{(Eq 3.1)}$$

where I and I_1 are the sound intensity and reference intensity in watts per square meter (W/m^2) respectively, and r and r_1 are the respective distance and reference distance in meters (m). At larger distances (larger than the source size and larger than one wavelength — typically a few meters or less), the sound intensity and sound pressure are approximately related according to:

$$I = p^2 / (\rho c) \quad \text{(Eq 3.2)}$$

where p is the sound pressure in pascals (Pa), ρ is the air density (kg/m^3), and c is the speed of sound (meters/second). Neglecting wave interference and the (generally small) variations of density and sound speed, we can see from applying Equation 3.2 to eliminate I and I_1 from Equation 3.1, that the sound pressure generally decays with the inverse of distance from a sound source:

$$p = p_1 (r_1 / r) \quad \text{(Eq 3.3)}$$

where p_1 is the sound pressure measured at r_1, the reference distance.

The sound pressure level (L_p) in decibels (dB) is defined as:

$$L_p = 10 \; lg\left(p^2 \; / \; p_0^2\right) \quad \text{(Eq 3.4)}$$

where p_0 is the reference pressure (Pa), which for air is equal to 20 µPa.

The decay of sound pressure level can be expressed according to distance by substituting Equation 3.3 into Equation 3.4:

$$L_p = L_1 + 10 \lg\left(r_1^2 / r^2\right) \quad \text{(Eq 3.5)}$$

where Equation 3.4 is used in the form $L_1 = 10 \lg\left(p_1^2 / p_0^2\right)$ to give the sound pressure level measured at r_1. Using the relationship in Equation 3.5, it is possible to predict the sound pressure level at any point on the landscape.

In arriving at Equation 3.5, we have made many simplifications to the real problem of estimating sound propagation outdoors. In truth, there are _no_ nondirectional sources, the air and ground do absorb sound, the ground reflects sound with an appreciable time delay causing wave interference, nonflat ground causes sound diffraction, and the speed of sound varies with position and time to cause refraction of sound energy. Excellent reviews of sound propagation exist in the literature and offer better descriptions of these important effects (Attenborough 2002; Embleton et al. 1996).

Figure 3.2 displays the variation of sound pressure level with distance for an omni-directional noise source with measured sound pressure level equal to 110 dB at 200 m.

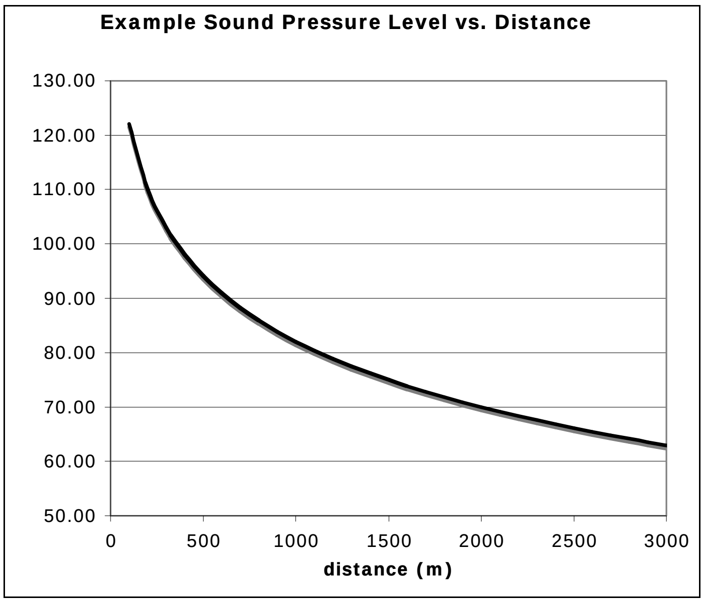

Figure 3.2. Sound pressure level as a function of distance for a source producing 110 dB at 200 m.

Consider a generalization of the inverse-square relation for sound intensity that captures the notion of anisotropic propagation. In some important cases, dissipation is not three dimensional (3-D), but rather two dimensional (2-D). For example, in the situation of a temperature inversion, which can frequently occur early morning pre-dawn under a cloudless sky, noise energy is refracted by the atmosphere back to the ground (Attenborough 2003; Embleton et al. 1996). Hard ground cover such as rock, encrusted sand, or water can then reflect the sound energy upward, to be refracted downward once again. Because most of the sound is confined to a layer, it can expand outward only in a ring (2-D), rather than a hemisphere (3-D). In this situation the sound intensity varies more like the inverse of distance, rather than its inverse square. Conversely, ground effects involving vegetation can absorb sound energy increasingly at higher frequencies and higher frequency sounds will also be absorbed by the atmosphere. Such effects can be captured in Equation 3.1 by introducing additional parameters geometric spreading coefficient and an absorption coefficient, so that sound intensity decays according to:

$$I = I_1\left(R^{n-2}r_1^2/r^n\right)\exp\left(-2\alpha r\right) \quad \text{(Eq 3.6)}$$

where n represents geometric spreading (n = 2 for hemispherical 3-D spreading, and n = 1 for 2-D confinement in a temperature inversion, for examples), and R is the distance where 3-D spreading changes to 2-D. Usually for sources near the ground, 100m < R < 400m so that, for distances near to the source, the geometric spreading is hemispherical. In Equation 3.6, α is an absorption coefficient for processes such as molecular absorption of sound by air, or attenuation by the ground shadow. In most situations, $\alpha < 0.0006\,\mathrm{m}^{-1}$, but the absorption coefficient can be appreciable for frequencies above 1 kHz and for highly absorbing ground surfaces. For the corresponding sound pressure level, we have

$$L_p = L_1 + 10\lg\left(R^{n-2}r_1^2/r^n\right) - 8.686\,\alpha r \quad \text{(Eq 3.7)}$$

The goal is to convert the sound intensity levels to a probability of complaint. The human ear perceives sound intensity logarithmically, and the dB logarithmic scale has been developed for practical communication of sound intensity. Therefore, expressing the sound intensity as a level in decibels is appropriate for associating an annoyance factor with the sound. Once the location of the noise generation is selected, an analysis can proceed to identify the associated decibel contours to identify potential conflicts with other land uses. For example, residential areas are generally considered tolerant of DNL levels of 65 dB and below, and levels of 55 dB or less are associated with no adverse impact (U.S. Environmental Protection Agency 1972). (The day-night level [DNL] is the 24 hour average sound level in decibels, after addition of 10 dB to levels from 2200 to 0700 hours. Its symbol is L_{dn}.) Thus, a noise contour drawn every place that $L_{dn} = 65\,\mathrm{dB}$ would surround the areas less suitable for residential use.

When planning future activities, the locations of existing receptors are already established, and the goal is to identify positions on the landscape where a noise generating activity might be located. Therefore, the sound level must be converted into a quantity that can be used as a probability of complaint. Schultz (1978) showed a consistently reported correlation between decibel levels adjusted for day-night (L_{dn}) and annoyance given by,

$$P = 0.8553 L_{dn} - 0.0401 L_{dn}^2 + 0.00047 L_{dn}^3 \quad \text{(Eq 3.8)}$$

where P is the percentage of those exposed to a given value of L_{dn} that were highly annoyed. This relationship was affirmed by Finegold et al. (1994).

If it is further supposed that the generator of this example is operated continuously throughout a 24-hour day, then its DNL is given by,

$$L_{dn} = L_1 + 10\lg(9/24) + 10\lg(r_1^2 / r^2) \quad \text{(Eq 3.9)}$$

where the second term in Equation 3.6 includes the 10dB penalty for 9 hours of nighttime operation.

These last two equations give us the ability to predict the percent of highly annoyed individuals from a community at a given distance from an example activity (Figure 3.3).

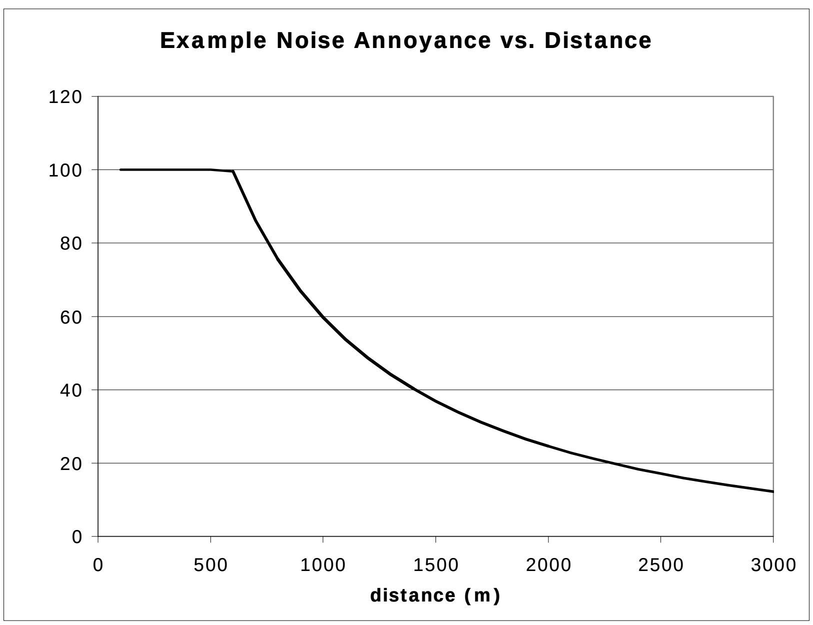

Figure 3.3. Percent highly annoyed vs. distance for the example noise source that produces 110dB at 200m distance, operating continuously around the clock.

Implemented within a raster geographic information system (GIS), it is possible to assign every grid cell a probability of highly annoyed individuals based on the location of a single receptor. Next, consider the case where there are multiple receptors (e.g., residences) of the potential annoyance on the landscape. Even with all of the things discussed thus far, the probability of complaint based on annoyance must still be determined.

Surprisingly, very little guidance is available about this subject. Of course, it will likely depend on many aspects of the situation, such as (1) the time available to register a complaint, (2) the perceived likelihood that filing a complaint will make a difference, and (3) the ability of the highly annoyed to determine the source location and then find the appropriate authorities, etc. In order to simplify the task, we will suppose that 1 out of every 8 people highly annoyed by noise will file a complaint about the noise.

Annoyance probability surfaces can be generated for each receptor. These numbers can be added together to determine the total number of people highly annoyed by noise.

Implementation

These equations were implemented with the Geographic Resource Analysis Support System (GRASS) (Goran 1989) running on a Linux computer. Software was developed using the C programming language (Kernighan and Ritchie 1978). The resulting program is called r.decay.noise and will become part of a future release of GRASS. Invoking the r.decay.noise program with the '-help' argument reveals the following help information:

Usage:

r.decay.noise [-v] input=residential_map output=name dB=decibel distance=distance power=power [height=height_of_noise_source]

Parameters:

input	map with integer number of individuals at each location
output	name of raster map to contain results
dB	known decibel level
distance	distance at which the decibel volume is known
power	decay rate of the sound as a power of distance
height	the height of the noise source (e.g., an aircraft)

The user-provided dB value can be a raw decibel level, an A-weighted value reflecting human perception of single events, peak sound level, sound exposure level (for sound over time), day-night average sound levels, or onset adjusted noise, depending on the particular needs of the analysis. Options are not provided within the program to adjust decibel levels based on the needs addressed by these different measures.

Consider the output image in Figure 3.4. The requested power of decay was 1.0 with a given probability of decay of 10% at a distance of 10km. The input map represented a single individual on a single location. Complaint within the innermost contour will be 100%, with contours at 80%, 60%, and 40% in the image.

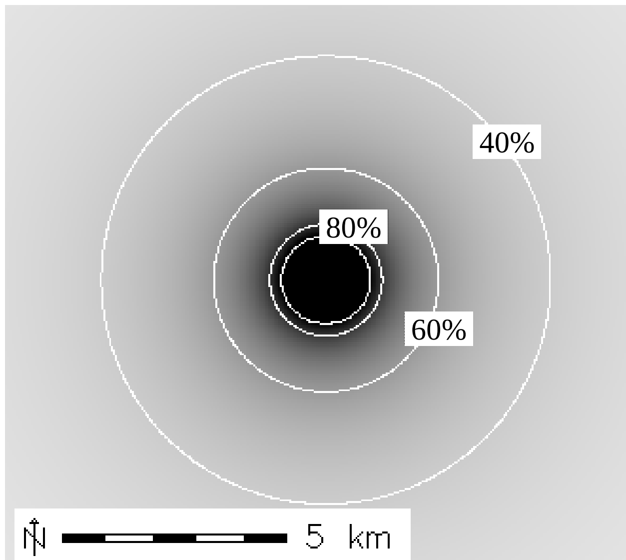

Figure 3.4. Sample decay of probability of complaint.

Application

Fort Benning is primarily in west central Georgia and has been known for 75 years as the "Home of the Infantry." It has fueled the economic development of Columbus, GA to the northwest, which is now growing in a manner that threatens to limit future training and testing opportunities. U.S. Highway 80 parallels the northern edge of the Fort, connecting Columbus with central Georgia. The highway provides the opportunity for people to settle "in the country" while enjoying relatively short drives to jobs in Columbus. The LEAMluc (Land use Evolution and impact Assessment Model land-use change) urban development model (Westervelt et al. 2004) has been used to project future settlement patterns along this route. The question is, "How will these projected patterns affect the probability of residences complaining about the training on firing ranges that exist within this area of Fort Benning?"

Consider a training annoyance that is associated with a 0.1% rate of complaint among residents at a distance of 1000m. An urban residential pattern was discerned from the U.S. Geological Survey's National Landcover

Data (NLCD) for 1993 and was evolved to 2030 using LEAMluc. Based on these maps and a sample annoyance algorithm, training tolerance patterns were generated and are reproduced in Figure 3.5 and Figure 3.6, respectively. Fort Benning is outlined in white and Columbus borders the installation to the northwest. The probability of complaint is represented by shades of gray, where black represents a 100% probability, fading towards

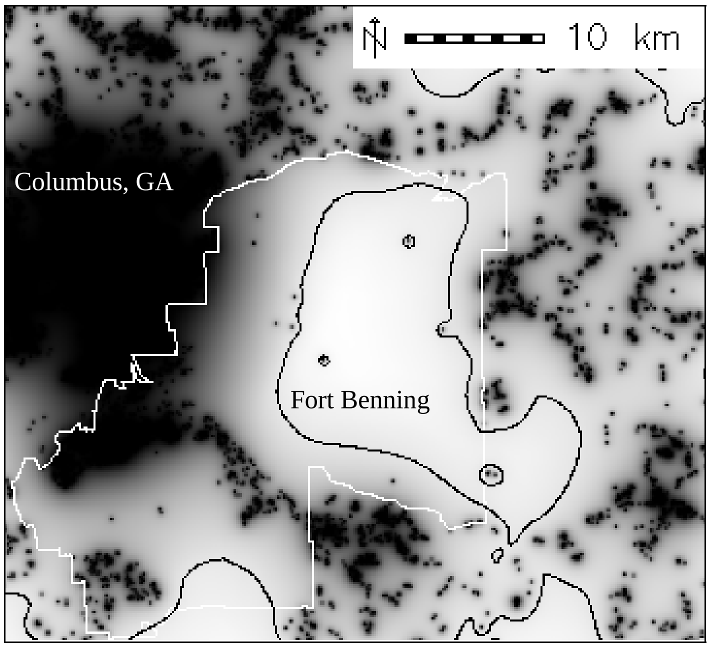

Figure 3.5. Estimated high noise tolerance areas for 1993.

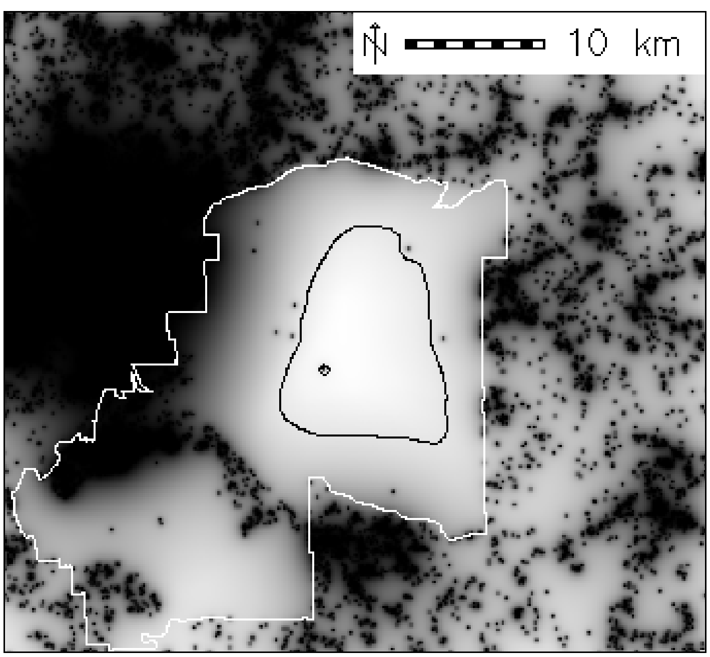

Figure 3.6. Estimated high noise tolerance areas after forecasted urban growth.

white – a 0% probability. A 10% probability contour was generated for the raster results and is displayed in the figures as a black line. Note first the shadow of the urban growth from the LEAMluc simulation outside the installation representing significant new settlement locations as well as denser urban areas, especially in the Columbus area. Now compare the black 10% complaint probability contour lines within the installation. Note the loss of the low probability of complaint area along the southern border and the significant shrinking of the area in the center of the northern part of the installation.

Discussion

When the past, current, or even future locations of military training and testing are known, it is possible to apply existing analyses and models to predict the impact of the training on surrounding natural and human areas. Beyond about 10 years, however, we do not know what the changes in training doctrine, weapon systems, and stationing of troops will be, and it becomes impossible to predict the impact of future training. Therefore, we have turned to predicting where training (on or off installations) could occur. The sample application, though not real, is realistic and indicates the ability to understand, predict, and visualize the impact of urban growth on future training and testing opportunities.

Properly calibrated, this approach will be useful for predicting future training and testing area opportunities with respect to noise, dust, smoke, and light pollution. Calibration will be approached in two ways. First, with respect to what we know about the physical transmission of noise, dust, smoke, and light, such analyses can give us insights into the strength of a training annoyance, and this information must be connected to the human psychology of annoyance. Our continued research will be looking at building tables of annoyance levels and decay rates based on the annoyance itself, the local attenuating factors (environmental and structural), and human psychology. Second, calibration can be accomplished through interviews with people that have experienced the annoyances. We expect to collect information through interviews that will allow us to associate the level of annoyance at a particular distance of an activity at various times of the day and year that will be statistically analyzed to establish useful working coefficients.

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14. ABSTRACT

The future training/testing capacities of military installations and their surrounding regions are increasingly based on today's smart regional planning in collaboration with surrounding cities, counties, and states. Developing urban patterns around installations can be steered in a manner that ensures the continued viability of the installation to support present and future missions. Researchers have developed a two-step process to link proposed regional plans to future training/testing opportunities. The first step is to project future urban patterns that are likely to develop. This document covers the second step: identifying where military training will be tolerated, in future urban patterns, by people living near installations. It includes discussions of mathematical modeling approaches that convert projected urban patterns into maps of where noise, dust, and smoke will be tolerated by surrounding communities and where light from the communities will not interfere with night training.

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