Environmental Noise Pollution on the HSU Campus

A Spatial Analysis Report by Henry Baker

Introduction

The following analysis was done to determine whether environmental noise pollution is a problem at HSU and if so, identify the sources and investigate what can be done to reduce the effects. It is important to consider the effects of background noise in a learning environment. A relatively quiet environment, free of distraction is important to student success. The study was conducted on the Humboldt State University campus, located within the city of Arcata in Humboldt County, California.

Included is a detailed account of the methods used in this study for measurement and analysis using sampling tools and Geographic Information Systems (GIS) software. Lastly, the study's results and conclusions, with suggestions for future investigations into noise pollution at HSU are incorporated. The study was done by sampling decibel levels around the Humboldt State University Campus.

The decibel, abbreviated dB, is a measurement of loudness and represents the intensity of air pressure from sound vibrations in the air. It is important to note that volume and decibel level are not the same thing. Decibels are a measure of wave intensity as opposed to volume, which is apparent loudness to the human ear (Wolfe). The values expressed in this report reflect average Db level during the sampling period. Intensity of the sound waves is only one component of noise and does not completely represent the phenomenon of noise but *is* measurable and quantifiable, unlike the other observable factors of noise. Apparent loudness to the human ear varies widely according to many factors, such as pitch, oscillating frequency, and sensitivity of the individual observing the sound.

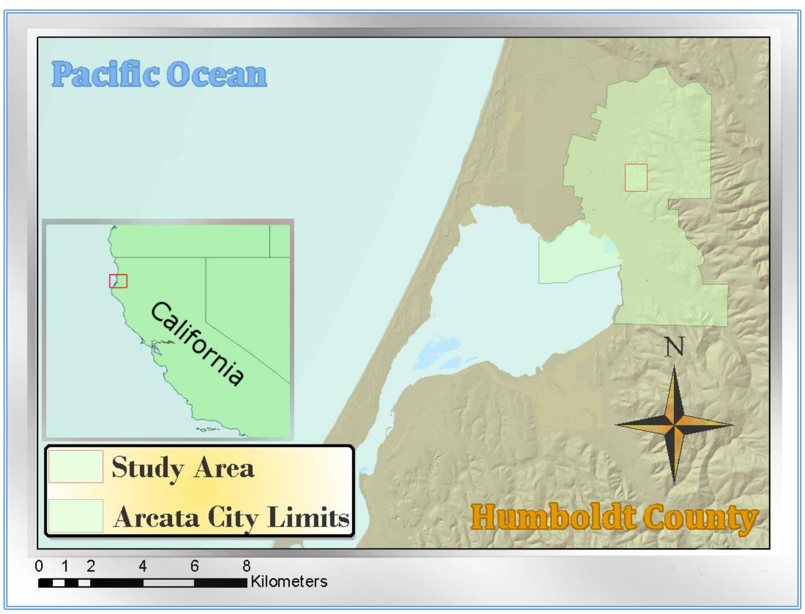

Figure 1: Location of the study

Methods

Pre-sampling analysis

I decided to sample a 25x25 meter grid of points within the open air areas of the HSU Campus. Pre-sampling analysis was conducted to determine the location of sample points. Background noise levels were sampled on Tuesday, November 11th, 2014 (Veterans Day) between approximately 10am and 4pm. Sampling was performed on the holiday because no classes were being held, no landscaping was being done and relatively few students were around. The values expressed in this study reflect only environmental *background* noise. During open school hours these locations fluctuate widely in noise level, however the background noise level is relatively constant with the exception of stationary objects such as air conditioning unit compressors and machines.

The Sampling was done using Sound Meter LITE, on an Android Galaxy S2 smartphone, since no professional sound meter was available through the academic departments. It should be noted that the smartphone is not professional level equipment and cannot detect noise levels below 25Db. Figure 2 (center) shows a screen capture from the Sound Meter LITE application. The application takes measurements of Db levels and displays the minimum, maximum and average Db levels over a 30 second duration. An orienteering compass and a pre-prepared map were used to locate the sample points around the HSU campus (Figure 2 right). Sampling was done by pacing out each point and taking a measurement and recording the average value directly on the field map. If an obvious source of noise was within the vicinity that is normally absent, such as a lawnmower or a person talking, the point was temporarily skipped and sampled later that day.

Short recordings were taken of three areas with high environmental noise to be used as examples (Table 1). The Samsung smartphone was used to make these recordings. Note that the recordings included alongside this report are not effective examples of the intensity of the background noise, rather they convey the *kind* of sound at a location. The samples are in .mp3 format.

The majority of analysis was performed using ArcMap 10.1 from Esri, Inc. Some tasks required the use of QGIS, an open source GIS software package. Other programs were used in the preparation of visualizations for this report.

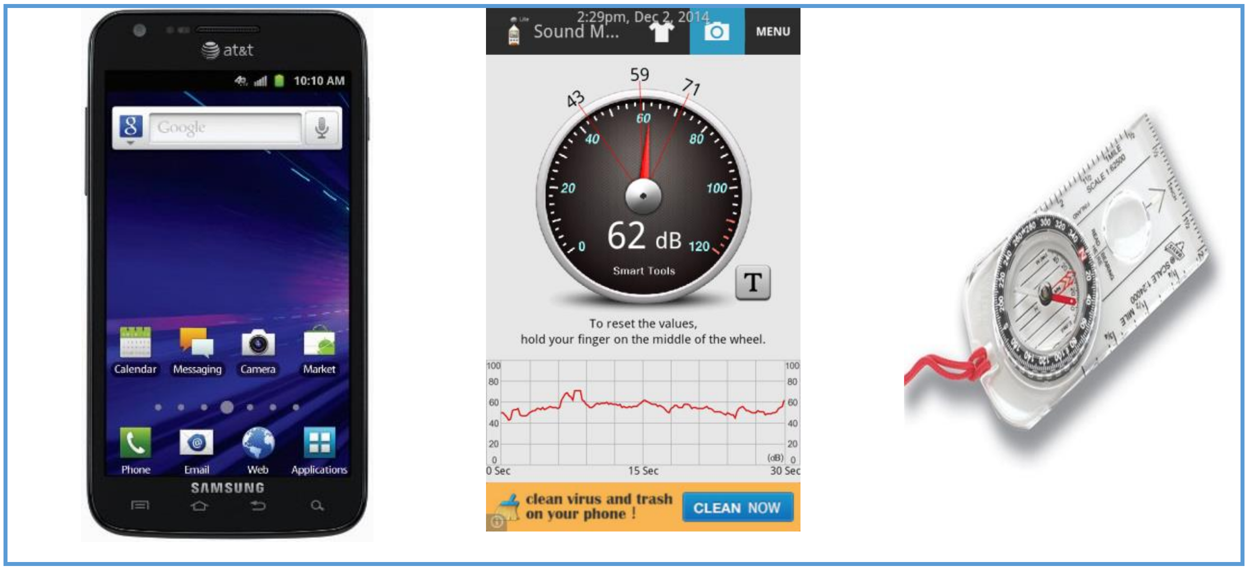

Figure 2: Left to Right: An android smartphone, Sound Meter LITE, an Orienteering Compass.

A campus boundary layer was not available through the HSU GIS Data Hub, so in lieu of a boundary map, one was created by intersecting the buildings shapefile with the Humboldt County Parcel shapefile. Additional parcels were added manually using the merge option while in edit mode.

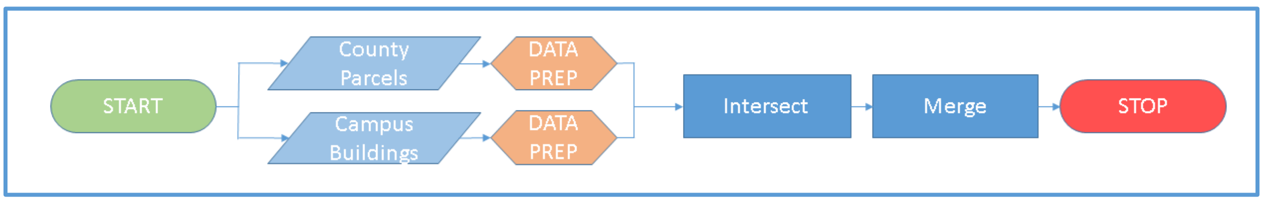

Figure 3: Flowchart for creating the campus boundary

I was only interested in the open areas, so additional shapefiles had to be removed using the erase tool. Some shapefiles, such as parking lots, forested areas and fields were not available through the Data Hub, so they were digitized, then removed from the open areas shapefile using the erase tool. A three meter buffer around streets and a two meter buffer around structures was removed from the open areas shapefile. The resultant shapefile was used for analysis.

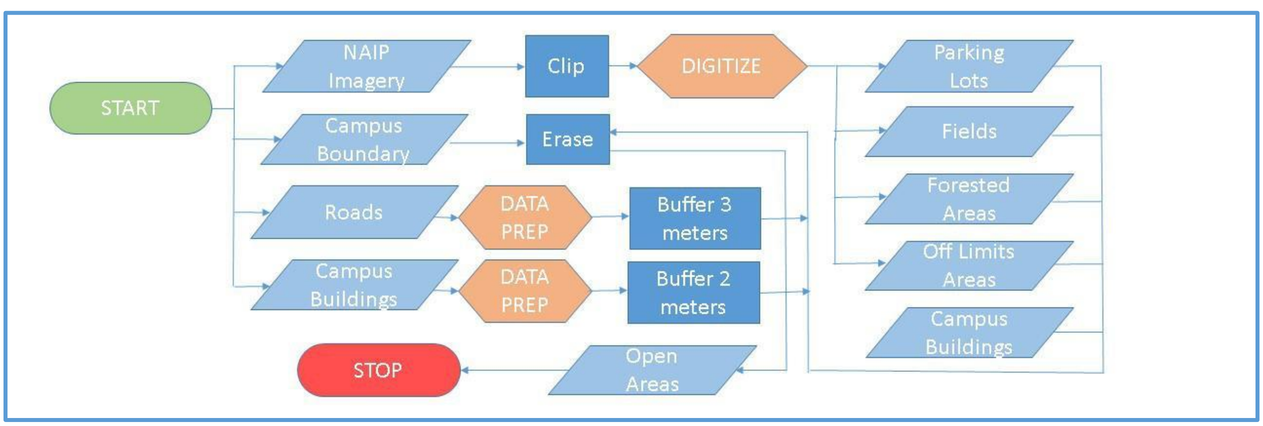

Figure 4: Flowchart for creating the sampling area

I required 25 meter equidistant sample points for data collection within the amended open space shapefile. To accomplish this, I converted the open space shapefile to raster format, with each pixel 25 meters on a side, then I converted the resultant raster into vector points. The sample points were spaced on a field map (Figure 6) with the buildings and campus boundary shapefiles for reference.

I manually removed points with areas of limited access as well as points which intersected with the digitized fields, parking lots and forested areas. After removing the points I was uninterested in, I was prepared to take the field map and sampling tools (Figure 2) out to collect data.

Thiessen Polygons or a euclidean allocation raster converted to a shapefile can be intersected with the open space shapefile to yield a zone around each sample point to be used for display. For my analysis, I used Thiessen polygons. It should be noted also that QGIS has a feature called "split" which allows for equal division of polygons into smaller polygons.

In order to sort the resultant grid of vector points in a manner conducive to data entry, a single point was created in a new layer file 200,000 meters north of the westernmost point. Using the near tool, a field was added to the sample points shapefile calculating proximity to the guide point. By sorting the new field in ascending order, the points were organized from West to East, North to South.

A new field was added titled "ddb," to represent decibel level and the data from sampling was input into the attribute table. After manual data entry, I combined the Open Space partitions with the Sample points using Spatial Join to produce my sampled polygon shapefile. (Figure 5)

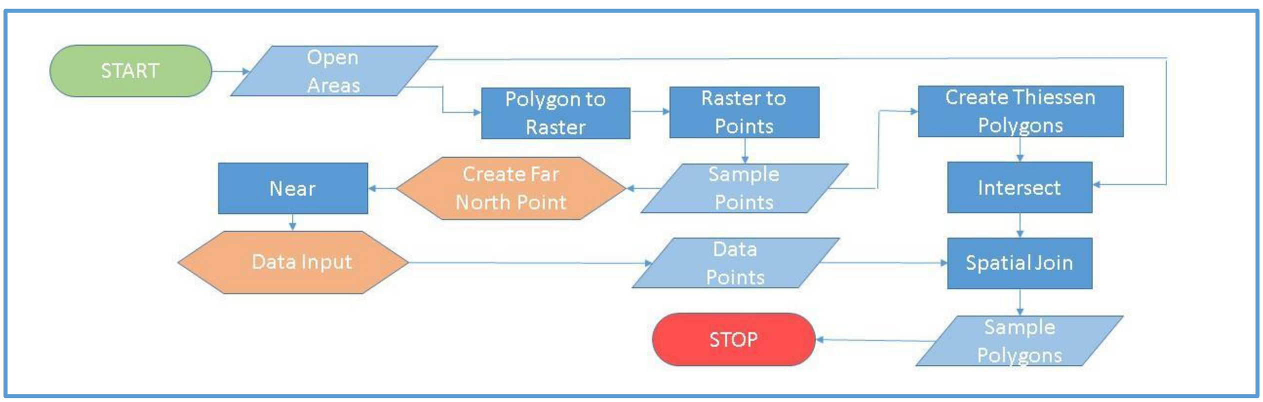

Figure 5: Flowchart for sample point organization and data entry

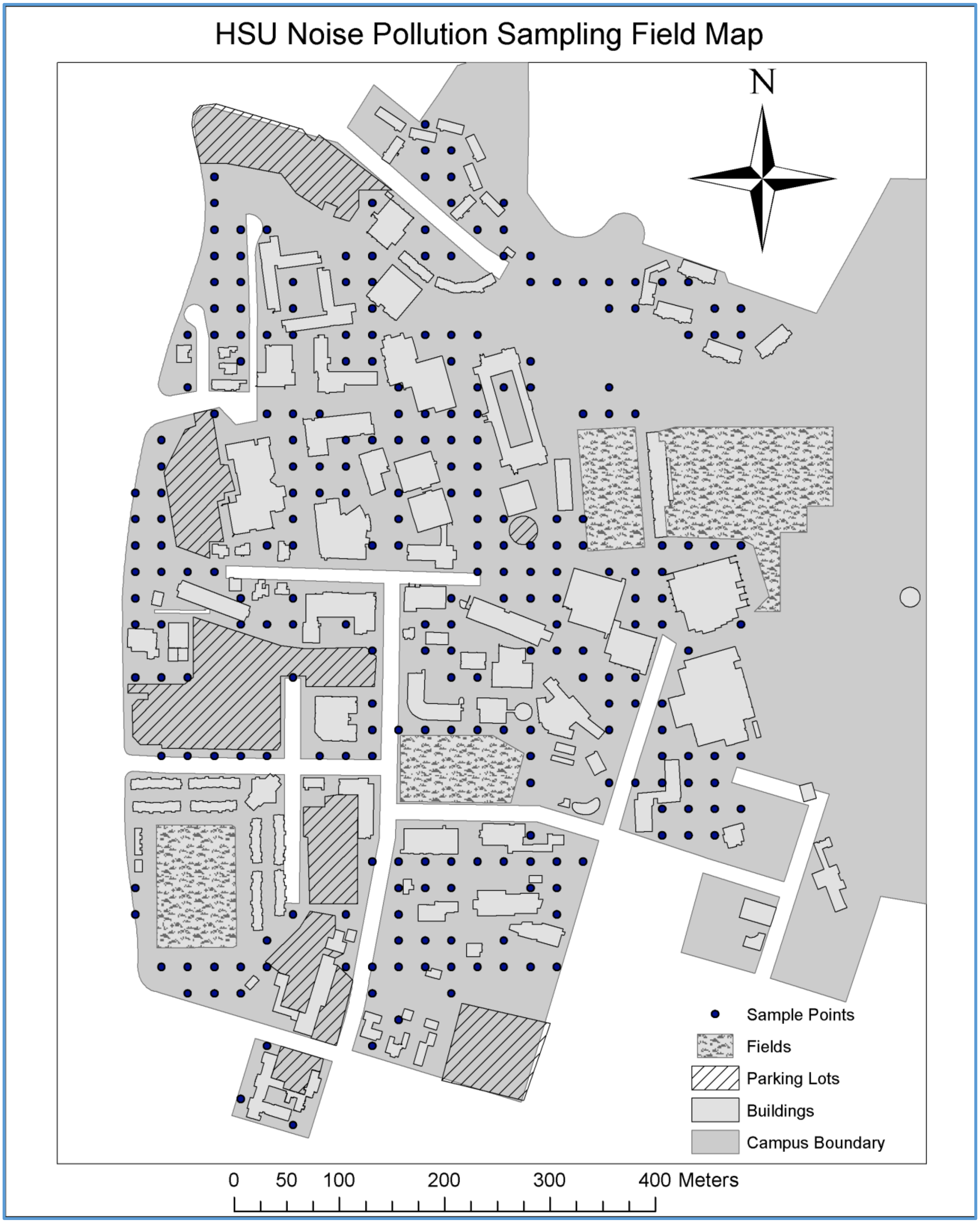

Figure 6: The noise pollution field map for the study (not to scale)

Post-sampling Analysis

Noise levels were compared with the major features of the Humboldt State University Campus. The background noise decay raster was used to find regions where the background noise level was 50 decibels or higher. This was compared with 10 meter buffers around roads, trees, parking lots, fields and structures (Table 2).

Figure 7 shows the common features of campus which were used to create Table 2. The parking lots and fields were digitized using the NAIP imagery. The campus boundary map created for this report and county parcels were used to aid in the digitizing process. While the digitized boundary map is not perfect it is sufficient for this study.

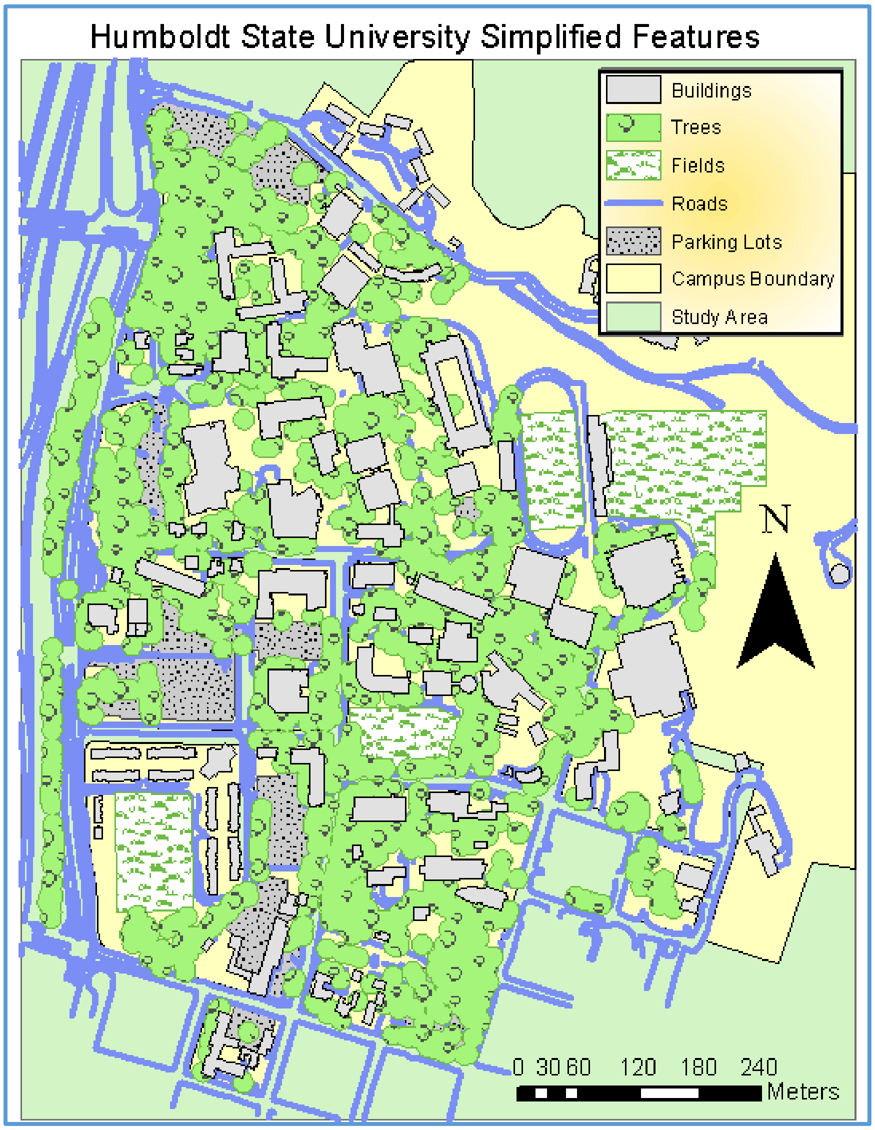

Figure 7: Simplified Features Map

A decay function representing the reduction in decibel level was performed on the sample points creating a raster image of the effects of background noise on campus. Noise decreases at a rate of six decibels per half distance from the origin. Since the study did not locate point sources of noise pollution, but rather regions of noise pollution, half the sampling distance was used as the distance from the origin. Our sampling distance was 25 meters, giving us a decay rate of -.48 decibels per meter. The equation in figure 8 was used to generate the map of decay over distance. Dbf represents the decibels at a given point, Dbi represents the decibel level of the nearest sample point and d represents distance.

$$(Dbf)(d) = (Dbi)-(Dbi)*0.48d)$$

Figure 8: Rate of noise reduction over distance

The background noise effect was also compared to a digital elevation model (DEM) to see if a correlation between elevation and background noise could be established (Figure 9). While there is a correlation between elevation within the sample area and decibel levels, the apparent effect from elevation change is more likely due to the effect of roads (Figure 14). ArcScene was used to create a 3D visualization of the decay function. The building layer was added to the map with adjusted base heights according to the DEM and extruded for better visualization. The appropriate heights of structures on campus are not accurately reflected in this visualization.

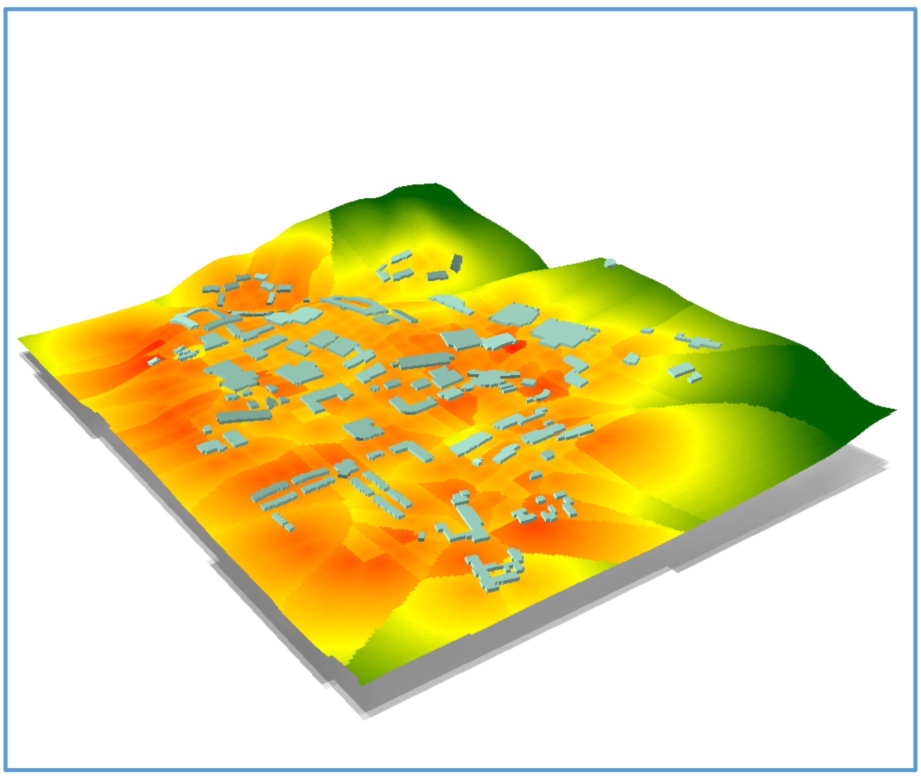

Figure 9: Background noise decay function 3d visualization

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In order to identify the sources of noise pollution on campus, I created a new visualization based on the thiessen polygons and extruded the polygons based on their decibel level to display the sample regions relative noisiness (Figure 10). I used a clipped raster from NAIP imagery and equated the base heights to the 30 meter DEM. The NAIP Imagery provides better context to the polygons.

Roads and forested areas outside the sampled polygons are visible to the reader. Extruded areas are color coded by decibel level as well to better discern the loudest areas. Only sampled areas are extruded. Forested areas, parking lots, fields, structures and the buffered zones around trees and roads were not sampled, so they do not contribute to this data set.

It should be noted that the polygons displayed in Figure 10 are not equal-area polygons, however each polygon contains a sample point and they vary from the mean within 200 square meters. I would have liked to have made each polygon the same size, but equal area polygons were not possible at this stage.

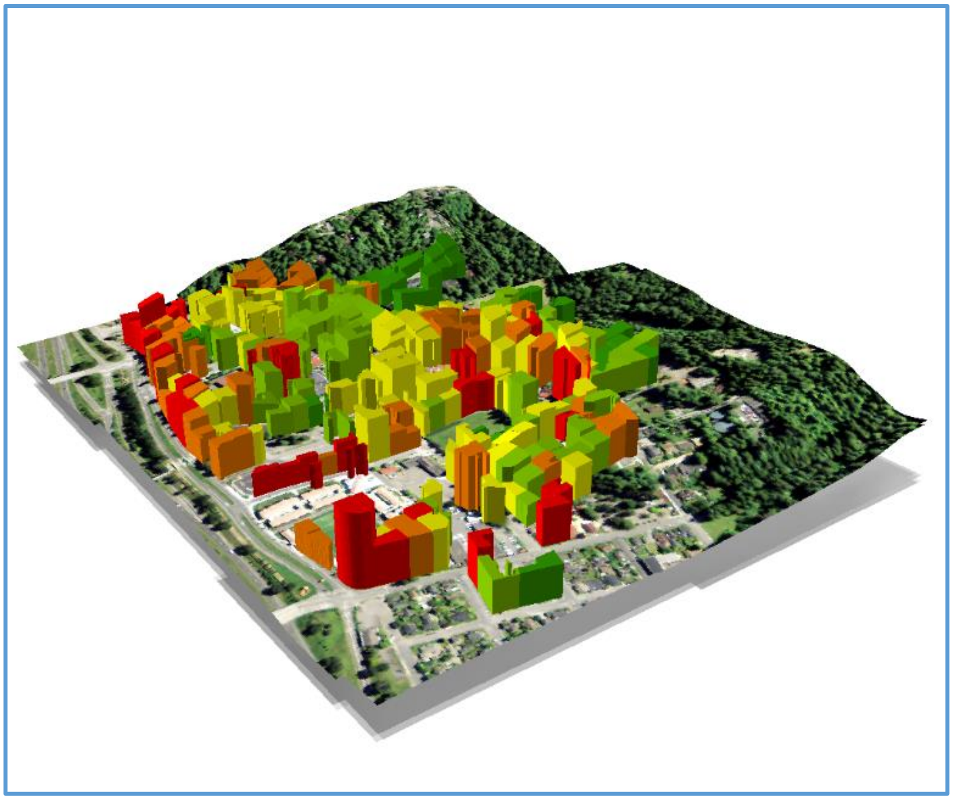

Figure 10: Extruded sample polygons

Results

Sample Polygons

When the decibel levels are combined with area they occupy, it is apparent that there are regions of high and low environmental noise intrusion (Figure 11). There is a clear East-West difference, due to road noise, as well as several hotspots around the campus interior. Fortunately, most of the severe Db levels are not located near structures, as shown in Table 2.

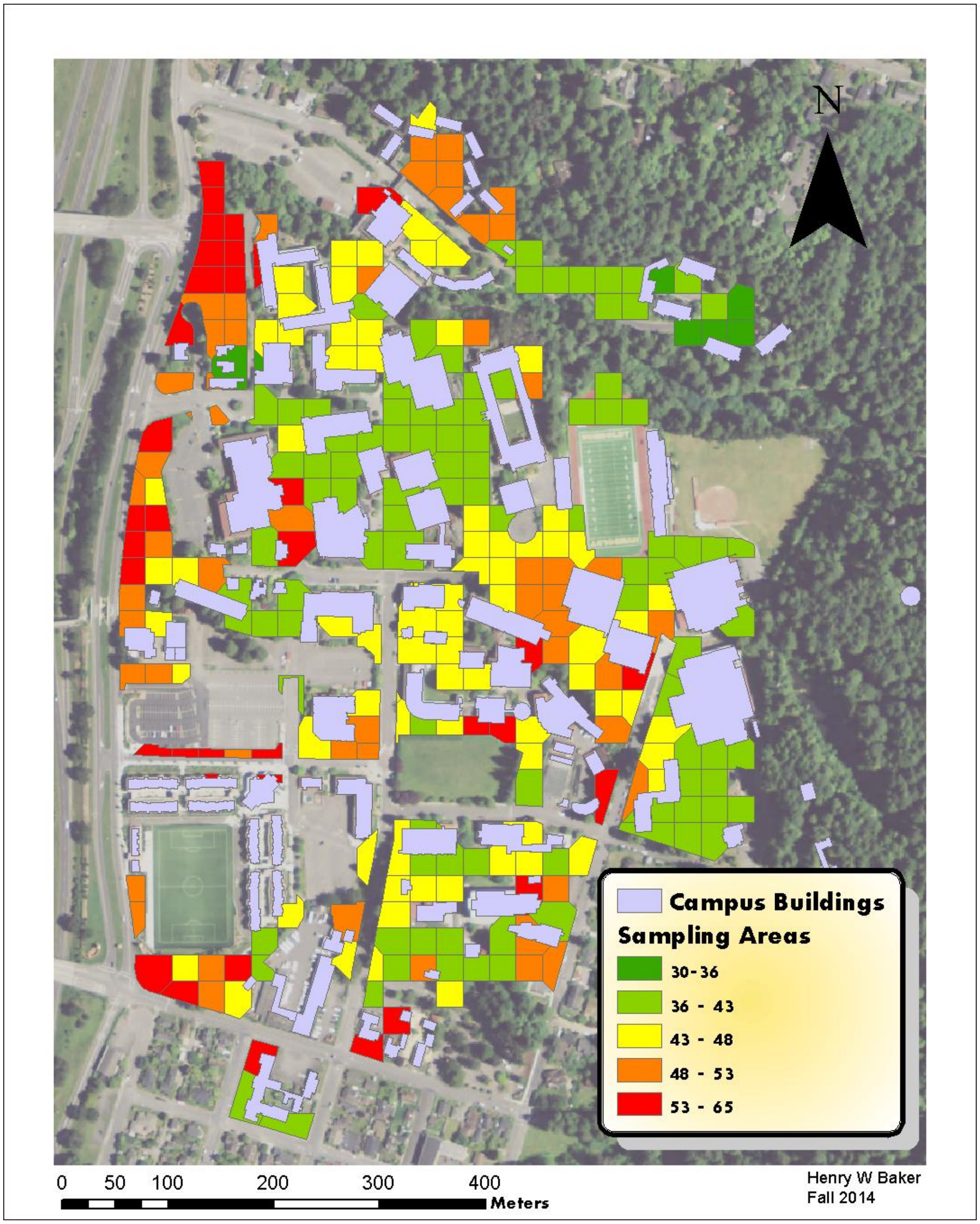

Figure 11: Polygons Based on Sample Points

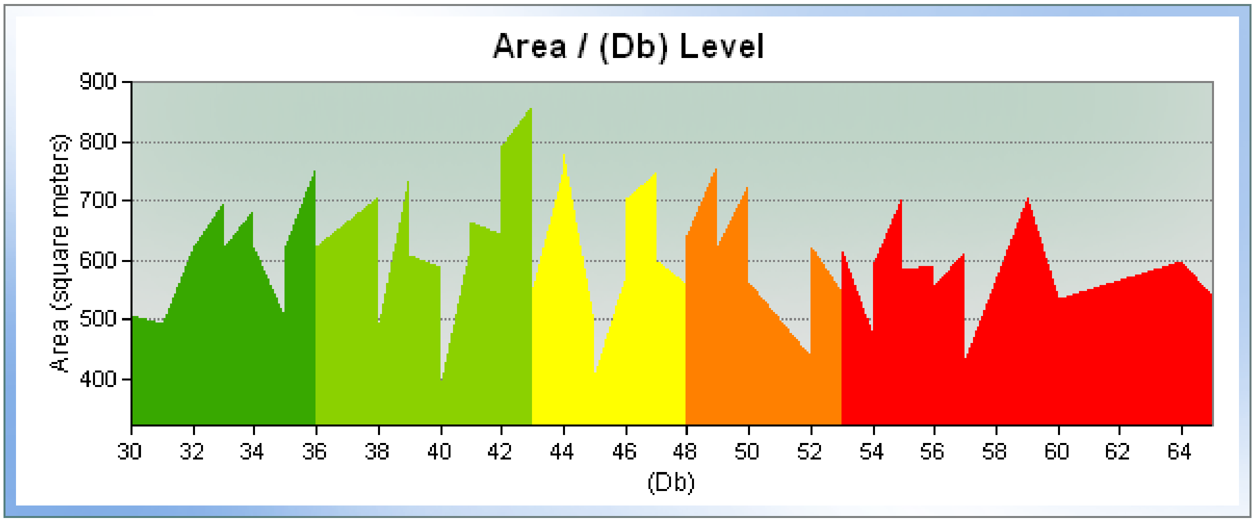

Figure 12: Area of Sampled Polygons / Decibel Level

Of the 262 sample polygons, 83 were greater than 50Db. The mean value measured is approximately 45.25 Db. Measured values ranged between 30 Db and 65 Db. Figure 13 shows the distribution of the measured values. The standard deviation is approximately 6.9 Db. The average value is below Environmental Protection Agency's recommended average exposure of 50Db each day. Decibels are logarithmic, so it would appear that background noise at HSU is within regulation; however, due to the many variables involved and the amateur equipment used in this study, no conclusion can be drawn as to whether noise is a problem at HSU.

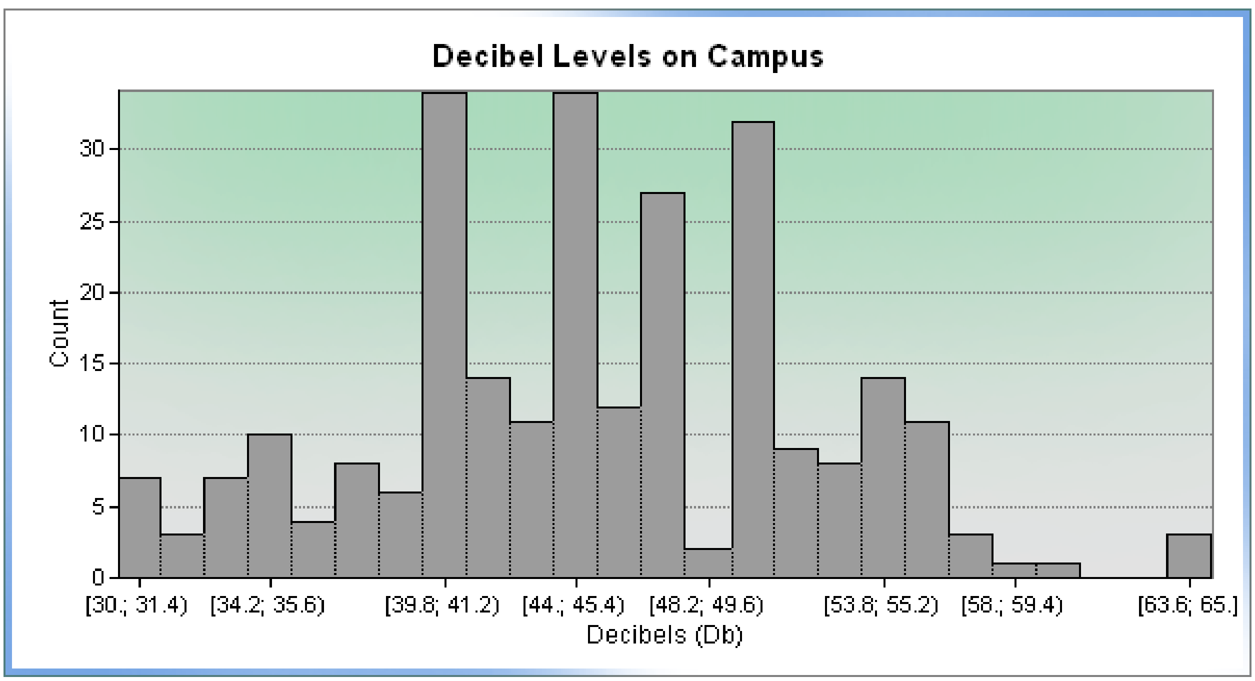

Figure 13: Number of Points Sampled / (Db) Level

Recordings

Location of Recording	Nearest Sample Level (Db)	Apparent Source
Hydrogen Station	53	Compressor
South side of BSS	66	Central Air
East of BSS	60	Electrical Box

Table 1: List of Recordings

Road Noise

Road noise is the most apparent contributor to environmental noise pollution. Figure 14 shows the background noise contribution created using the decay function in relation to the current streets shapefile, available through the HSU geospatial dataHub. Analysis on the data gathered Nov. 11th revealed that the total area with noise levels over 50 decibels was approximately 36,128 square meters, of that, 32,417 square meters was within 10 meters of a road. With 89.72 percent of noisy areas near roads, it is highly likely that roads are the cause of the majority of environmental noise at HSU. LK Wood Boulevard, directly east of campus is one of the dominant features of the study, contributing the most to the easternmost regions of campus where measured Db values are consistently high.

Environmental Noise by Feature

Feature	total area (square meters)	area over 50 decibels (square meters)	percent coverage over 50 decibels
Roads	208,889	20,170	9.65%
Trees	207,578	23,187	11.17%
Parking Lots	34,130	18,280	53.56%
Fields	38,860	5,783	14.88%
Structures	226,739	14,358	6.33%

Table 2: Noise by feature

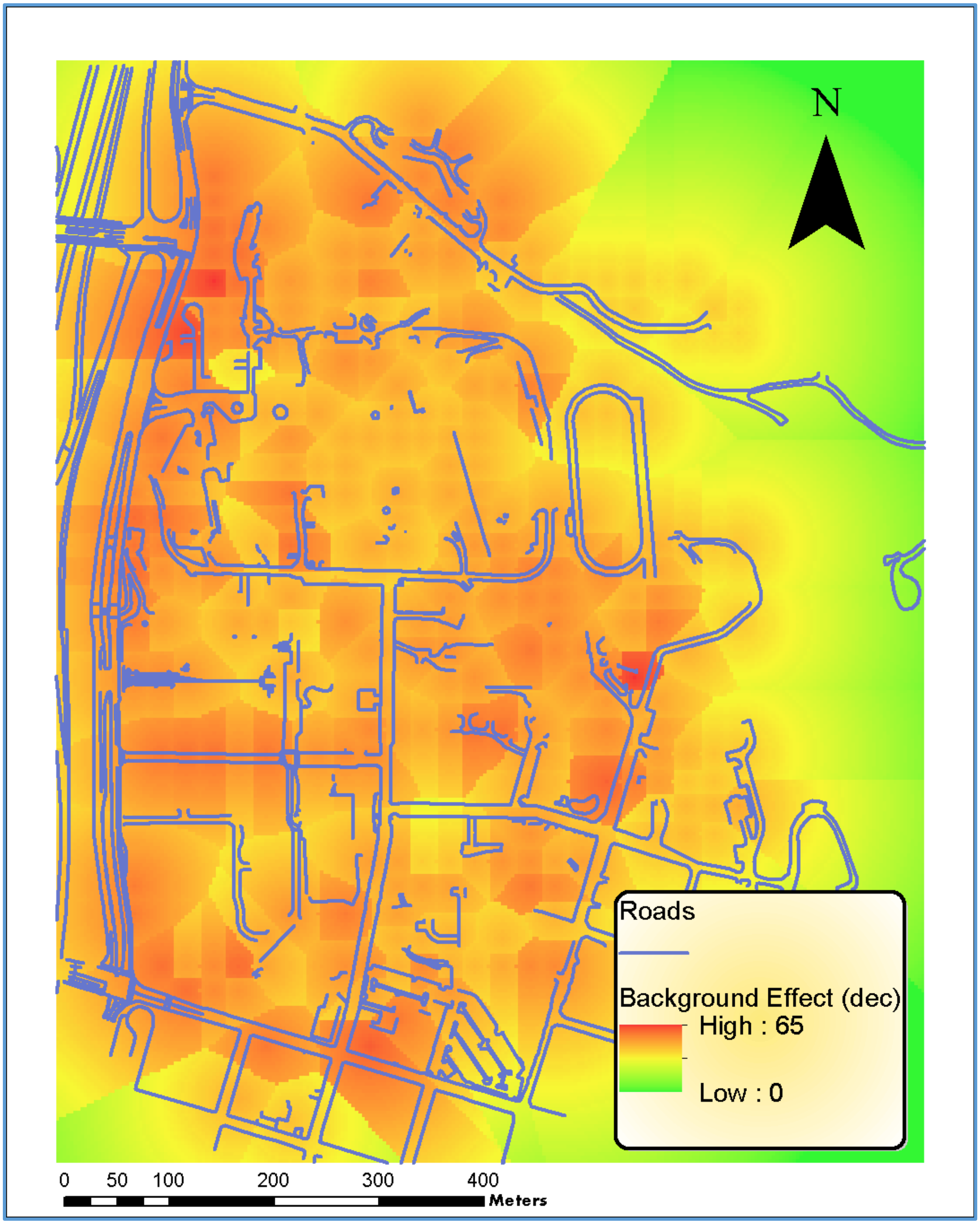

Figure 14: Map showing roads and noise on campus

Trees

It's commonly held that trees are an effective way of reducing environmental noise. Of the 36,128 meters with decibels over 50, 33,385 square meters had tree coverage within ten meters, (according to the HSU tree database). Using the current tree data, we can estimate that approximately 92 percent of the noisiest areas had trees. It would follow that trees had no effect on environmental noise, however, this is inconclusive, because more than ninety percent of the total area sampled had trees and trees are a major feature of the Humboldt State University Campus.

According to the Federal Highway Administration, a 200 foot thick barrier of dense foliage only reduces noise levels by 10 Db. (FHWA)

There are a substantial number of trees which have been planted along the western boundary of campus, presumably to reduce noise from the 101 Highway and LK Wood Boulevard. An additional study might be needed to determine whether trees are successfully blocking street noise from polluting the inner areas of campus. Determining whether there are better methods of blocking noise than planting trees, such as noise canceling panels or strategically placed white noise generation, would also be beneficial to future planning involving noise on the HSU campus. Further research might also be done to determine if in fact planting trees is an effective noise reduction, which kinds of foliage are most effective in the reduction of environmental noise.

Notable Sites

Creekview Student Apartments

When considering a strategy to reduce noise pollution, it is important to examine who is affected and where. For example, the most consistently quiet sample points were found around Creekview Student Apartments, in the Northwest corner of campus. Environmental noise pollution was in the 30-35 decibel range, the most consistently quiet region of the HSU campus. The low levels of environmental noise were likely because Creekview is surrounded by forest on all sides and has minimal come and go traffic. Creekview is also the furthest dorm from the 101 Highway.

Figure 15: (Creakview, left. Campus Apartments, right) Courtesy Humboldt State Housing and Dining

Analysis showed that there was a considerable difference in background noise between the Freshman/Sophomore and Junior/Senior dorms, the latter being more quiet. Environmental noise was in the 50 decibel range around Campus and Canyon apartments as well as Jolly Giant Commons. Therefore, it should be noted that, in this sense, environmental noise affects some students more than others. This study did not include environmental noise data *inside* structures, noise inside structures is likely more significant to student wellness than outside noise. Interior sampling requires more precise equipment than what was available at the time of sampling.

It is unknown at this time whether the noise in the Freshmen/Sophomore dorms is due to the residents or environmental factors. The initial results might suggest that the difference may be the Freshman/Sophomore dorms proximity to nearby streets and parking lots. Follow up studies could be done to determine the causes of noise over large areas.

Fish Hatchery

The east side of the fish hatchery generates a considerable amount of noise and was a noticeable noise hotspot on our polygon map. The source of the noise is the aerator pictured in Figure 16. Not only were the decibel levels high at this location, but the noise carried over to surrounding sampling areas. The closest sample point, which was located on the nearby sidewalk was in the immediate vicinity and unshielded from the source except for the chain link fence separating the Wildlife complex from the street.

Science A

The area around Science A was slightly louder than the area surrounding the other buildings. The source of the noise appears to be the central air units located on the south side (figure 17) and the rooftop of Science A. Large machinery such as air conditioning units and electrical boxes generate a rhythmic, consistent sound which may not be distracting to all students.

Figure: 16: The east side of the Hatchery

Figure: 17 Air vents on the south side of Science A

Conclusion

The results of this study show that the largest contributor of environmental noise to the HSU campus is road noise due to the proximity of the 101 Highway, LK Wood Boulevard and 14th Street. Sound waves reflect, and in some cases are amplified by relatively smooth surfaces including concrete, sheet metal and glass. This is a possible explanation of the hotspot along Harpst Street, since no vehicles were present on Harpst Street while samples were being taken. There were vehicles, however on LK Wood Boulevard. It is my opinion that road noise from LK Wood Boulevard and Highway 101 is reflects off the concrete wall along Harpst Street where higher Db levels were detected.

In Table 2, parking lots are the common feature class which has the strongest correlation with environmental background noise. This might be attributable to the abundance of smooth surfaces in these areas or the absence of trees or perhaps a combination of the two. Further research into the effects of smooth surfaces and trees on noise pollution would be highly beneficial to our understanding of environmental noise management.

Additional environmental noise hotspots were near central air systems and in one case, equipment inside the Fish Hatchery. Further investigation into air conditioning systems and machinery on campus may lead to potential environmental noise management solutions relating to the interior of the HSU campus.

This study does not include factors of environmental noise which are part of *perceived* loudness and the effects of noise pollution on student success. One such way to determine if noise pollution a distraction to students would be through direct interaction with the students themselves. A survey of students, perhaps distributed through email, could answer this question. A survey could be an effective and inexpensive way of determining if environmental noise management should be a priority at HSU. Additionally, once foot traffic data for campus is gathered, we will be able to see where and when students are effected by environmental noise. Future studies on environmental noise on campus may find additional hotspots not detected by this study due to the temporal nature of some sources of environmental noise.

Suggestions for Environmental Noise Management at HSU

- As machinery such as the central air, heating and cooling systems are replaced; the replacement systems should be chosen based on their quietness.
- Investigate the effectiveness of trees on environmental noise compared to other solutions.
- Survey students about whether environmental noise is among their concerns.
- Erect noise barriers made of materials that have a weight to surface area ratio of three pounds per square foot and have no gaps or perforations. Examples of potential materials are oriented strand board (OSB) or hay bales. Aesthetically pleasing barriers might incorporate vertical gardens into the landscape.
- Noise barriers or parapets should be installed around noisy rooftop machinery.
- Future construction projects should limit the proliferation of smooth, flat surfaces such as glass, concrete and sheet metal.

Acknowledgements

Software
Arcmap 10.1 Esri Inc.
ArcScene 10.1 Esri Inc.
qGIS Valmiera 2.2.0
Sound Meter LITE

Data
Humboldt County GIS
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HSU DataHub
National Map USGS

Images
HSU Housing and Dining Website
Henry Baker
Google

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