APPENDIX K
Noise Analysis

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FINAL

Wyle Report

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Noise Analysis for the Inner Harbor Navigation Canal (IHNC) Lock Replacement Project

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Executive Summary

Acoustical analysis was conducted to assess the noise impacts resulting from the replacement of the Inner Harbor Navigation Canal (IHNC) Lock and construction of associated infrastructure. The noise assessment addressed noise and vibration emissions from pile driving operations and other construction activities, as well as railway traffic and vehicular traffic, including traffic that will be detoured through adjacent neighborhoods. Several construction scenarios were modeled including no action, IHNC construction and detours, and future conditions upon completion of the project. Results in terms of the day-night average sound level (DNL) were compared with the U.S. Department of Housing and Urban Development (HUD) criteria for land-use compatibility.

Calculated average daily DNLs due to IHNC construction activities and related traffic detours will exceed the HUD allowable level of DNL 65 dB in several residential areas in the vicinity of the construction site and along primary traffic routes. In some residential areas during construction, DNL is expected to exceed DNL 75 dB, which is considered unacceptable noise exposure under the HUD guidelines. Computer-generated noise maps for each modeling scenario are provided with the report.

Results from prior vibration measurements of general construction activities and pile driving operations were analyzed and compared to acceptable standards on human-response to vibration. It is estimated that the lower range of vibrations in the surrounding communities will be under the acceptable vibration value and will not be perceptible by people. However, the upper range of vibrations generated by the construction activities and pile driving are expected to exceed the acceptable level, will be perceptible to people and may generate adverse reactions. The measured vibration levels were also compared to the threshold of structural damage to buildings. The proposed construction activities or pile driving will not adversely impact any structure or building in the vicinity of the construction site outside the floodwalls.

1.0 Introduction

Gulf South Research Corporation (GSRC) retained Wyle Laboratories under contract No. W912P8-07-D-0016 from the U.S. Army Corps of Engineers for Inner Harbor Navigation Canal (IHNC) Lock Replacement Study, Vehicular Traffic and Noise Impact Study Update, to provide assessment of the noise impact resulting from the replacement of the Inner Harbor Navigation Canal Lock and construction of associated infrastructure. The project is located in New Orleans, Louisiana. The noise assessment addresses noise and vibration emissions from pile driving construction activities and the vehicular traffic that will be detoured through adjacent neighborhoods during the construction period.

The project involved four major tasks. The first task was to assess the no action alternative (Plan 1), i.e. the existing ambient noise levels without implementation of the project. Wyle used historical data available primarily for aircraft noise from nearby airports to estimate the existing average noise levels at the site. This analysis is described in Chapter 2.0 of the report.

The second task included traffic noise analysis with assessment of changes in noise impacts from variations in traffic patterns expected for roadways in the vicinity of the project for major construction alternatives (Plan 3). The traffic volume data for the analysis was provided by the Regional Planning Committee (RPC). Chapter 3.0 describes the methodology of modeling the traffic noise. A description of the railway noise sources in the vicinity of the site is also provided in this chapter. The modeling results are provided and discussed in Chapter 6.0.

Construction noise is another major component of the project noise impact at the site. The third task included noise analysis of construction activities. Pile driving is the most significant construction noise source. Wyle performed the construction noise modeling and analysis based on the operational information provided by GSRC for various project alternatives. The construction noise sources are discussed in Chapter 4.0 of the report.

The noise modeling approach used for the study is described in Chapter 5.0, with the modeling results presented and analyzed in Chapter 6.0.

The fourth task was the assessment of the vibration impacts from pile driving alternatives in the vicinity of the project. It was primarily based on the measurement data obtained during the vibration monitoring that was carried out by USACE in the adjacent neighborhood in 2000. Wyle used the data provided in that study and applied it to various locations of interest. Chapter 7.0 describes the results of this assessment.

Conclusions for the study are provided in Chapter 8.0.

1.1 Effects of Noise

Noise is generally described as unwanted sound. Noise levels are typically expressed in decibels (dB). A decibel is a logarithmic ratio between a measured quantity and a reference quantity. Due to the logarithmic nature of the decibel, a sound that is 10 dB more (or less) than another sound is perceived as being twice (or half) as loud. Weighting scales are often applied to a noise levels. A common weighting is A-weighting. The A-weighting is representative of the sound level as perceived by a typical, healthy person. The A-weighting discounts low and high frequency content. A-weighted noise levels are used consistently throughout this report. For a more detailed explanation of noise metrics and the effects of noise refer to Appendix A.

HUD noise requirements for residential areas are provided in [1]. Assessment of the compatibility of land use near noise sources is based on Day-Night Level (DNL). The DNL is an A-weighted average noise level calculated based on the noise levels over a 24-hour calendar day, with a 10 decibel (dB) penalty added to noise from midnight to 7 a.m. and from 10 p.m. to midnight.

While the HUD exterior noise level goal is DNL 55 dB, DNL of 65 dB and below are considered "acceptable and allowable" [1]. If exterior noise levels exceed DNL 65 dB then noise mitigation measures must be taken. HUD quantifies DNL levels for residential areas into three categories:

- **Acceptable (not exceeding 65 dB)** – The noise exposure may be of some concern but common building construction will make the indoor environment acceptable and the outdoor environment will be reasonably pleasant for recreation and play.
- **Normally Unacceptable (above 65 dB but not greater than 75 dB)** – The noise exposure is significantly more severe; barriers may be necessary between the site and prominent noise sources to make the outdoor environment acceptable; special building constructions may be necessary to ensure that people indoors are sufficiently protected from outdoor noise.
- **Unacceptable (greater than 75 dB)** – The noise exposure at the site is so severe that the construction costs to make the indoor noise environment acceptable may be prohibitive and the outdoor environment would still be unacceptable.

2.0 Ambient Noise Levels

To assess the no action alternative, it was necessary to estimate the existing ambient noise levels at the IHNC lock replacement site without implementation of the project. Also, due to the volume and complexity of the project in the unusual post-Katrina environment, it was important to review the extents and actual conditions of the site for incorporating appropriate acoustical information, parameters and details in the noise model and analysis for the future conditions. Two major sources contributing to the existing noise environment in the vicinity of the project and included in the analysis were the aircraft and vehicular traffic. These conditions are discussed in more details in the sections below. Railway noise is discussed in Chapter 3.0.

2.1 Site Visit

Wyle engineers visited the IHNC site and surroundings on March 13, 2008. The study area included the IHNC, three bridges (St. Claude Avenue, Claiborne Avenue and Florida Avenue), proposed new lock and levee construction areas, as well as major roads and adjacent neighborhoods in Lower and Upper Ninth Wards. The existing conditions on the site and extents of the proposed construction areas were reviewed and photographed for documenting certain details important for the subsequent acoustical modeling and analysis. The existing road layout and location of the proposed road in St. Bernard Parish were studied. The existing building conditions were also reviewed to assess the extents and density of the constructions in various neighborhoods for the acoustical modeling of the area.

Two spot noise measurements were performed during the visit to assess the existing noise levels at the site. A Larson-Davis Model 831 Sound Level Meter/Analyzer was used for the measurements. The average A-weighted sound level was measured for the duration of 20 or 40 seconds at the locations when no traffic was present on the nearby streets. Description of the measurement locations and results are listed in Table 2-1.

Table 2-1. Measured Ambient Noise Levels

Location and Details	Average Sound Level L_{eq}, dB
Field at Dauphine St. and Sister St. in Holy Cross neighborhood; general ambient noise	48
Top of IHNC levee wall at the entrance from Mississippi River; idling barge in the canal and some industrial noise across the waterway	53

2.2 Existing Aircraft Noise

The site's exposure to aircraft noise was evaluated for civil and military airports within 15 miles of the site. Those included the Naval Air Station (NAS) JRB New Orleans (approximately 10 miles southeast of the site), New Orleans Lakefront Airport (4 miles north), and Louis Armstrong New Orleans International Airport (14 miles west). Two other small airfields, namely Southern Seaplane (7.5 miles south) and Braithwaite Park (10 miles south) conduct only infrequent small aircraft operations, are located far from the site, and provide no significant noise impact or noise level data; these airfields were not considered in the study.

Noise contours for NAS JRB New Orleans were obtained from the Base General Plan Update published on the web site [2]. From the noise map dated May 2005 it was determined that the Day-Night Average Sound Level (DNL) contour of 65 dBA does not extend beyond approximately 2.1 miles from the station. The DNL 60 contour does not extend beyond approximately 3.9 miles from the station. It was concluded from this data that the aircraft operations at NAS JRB New Orleans provide no significant noise impact for the project site.

Noise contours for New Orleans Lakefront Airport were obtained for the airport conditions in 1993 and activity forecast for 2015 from the Master Plan Update Environmental Impact Statement for the airport [3]. Despite a slight increase of the noise contours for the future conditions, to the south of the airport the DNL 65 contours are shown to extend along IHNC only to U.S. Route 90. That is approximately 2 miles north from the Florida Avenue Bridge, not reaching the project site. Based on this data, it was determined that the aircraft operations at Lakefront Airport provide also no significant noise impact for the project site.

No noise contours were available for the Louis Armstrong New Orleans International Airport. However, due to the airport runway layout, it is anticipated that the aircraft operations are performed whenever possible to the west of the airport rather than to the east and over the city. The aircraft operations data reported by the Federal Aviation Administration (FAA) New Orleans Air Traffic Control for the airport [4] confirm that only 7% of the arrivals and 18% of the departures flew over the city in 2002 for aircraft operations on the east/west Runway 10/28. Taking into account also a large distance from the airport, it is not expected that the DNL 65 contours would extend to the project site or surrounding areas.

Overall, based on the information available, the aircraft noise impact for the project site and immediate vicinities is not considered significant.

2.3 Existing Traffic Noise

Roadway and railway noise sources are described in Chapter 3.0. Noise contour maps for existing (2008) roadway and railway traffic are provided and discussed in Chapter 6.0.

3.0 Traffic Noise Sources

Existing and future roadway and railway traffic noise analysis was conducted for the project site. Roadway traffic volumes are not expected to be affected by construction activity at the construction site except during the N. Claiborne Bridge replacement. During the bridge replacement, N. Claiborne Ave. will be closed between Forstall St. and France Rd. for approximately six months. For that duration traffic will detour to Florida Ave. Railway traffic volume is expected to remain constant over the duration of the lock replacement project.

3.1 Roadway Traffic

Three roadways cross the IHNC: Florida Avenue, N. Claiborne Avenue, and St. Claude Avenue Bridges. Each of the three bridges at the crossings will undergo construction during the project.

A lift-style bridge constructed along Florida Ave accommodates one lane of traffic and one railroad track. A second Florida Ave. bridge is planned to be built parallel to the existing bridge to increase traffic flow. Construction of this second bridge was originally planned to be completed prior to the IHNC lock replacement project. Delays have pushed construction back to coincide with the lock replacement. The existing Florida Bridge will remain open and therefore not affect traffic flow during construction of the second bridge. Construction of the second bridge is not part of the IHNC lock replacement project and therefore not included in the noise analysis.

The N. Claiborne Ave. Bridge will be closed for approximately six months in the year 2014 to replace the towers and lift span. The towers will be heightened to provide increased clearance for water traffic on the IHNC. Road traffic will be detoured to Florida Ave. during the N. Claiborne Bridge closure. This detour will significantly alter traffic volumes because N. Claiborne Ave currently has the highest traffic capacity for roadways crossing the IHNC and Florida Ave. has the lowest.

The St. Claude Bridge will be replaced during the lock replacement project. A temporary single-bascule bridge will be constructed adjacent to the existing St. Claude Bridge. Traffic will then be diverted to the temporary bridge while the existing bridge is demolished and replaced with a low-level double-bascule bridge. The temporary bridge will then be demolished. Traffic flow is not expected to be significantly altered due to the immediate proximity of the temporary bridge during the replacement of the St. Claude Bridge.

Average daily traffic (ADT) volumes and vehicle distributions were obtained from the April 2008 traffic study commissioned by the Regional Planning Commission (RPC)[5]. The ADT by road segment was provided in the form of geographical information systems (GIS) shape-files for the roads shown in Figure 3-1. This included the three roads which cross the IHNC and select north-south arterial roads, such as Caffin Ave., Forstall St., and France Rd, all shown as yellow lines. No roadway traffic data was included in the traffic study for roads not marked as yellow lines. Therefore these roads were not included in the noise analysis. The omitted roadways were all residential roads. It was assumed that traffic on these roads is minimal and not a significant noise contributor.

The "Centroid Connector" lines, seen in Figure 3-1, are an artifact of the shape-file which quantifies vehicle and pedestrian movements between regions of the traffic study area. This data is region-specific and not road segment-specific and therefore was not included in the traffic noise analysis.

Roadway vehicles are typically grouped into five acoustically significant types, i.e., vehicles within each type exhibit statistically similar acoustical characteristics. These vehicle types are consistent with the Federal Highway Administration (FHWA) Traffic Noise Model (TNM), and are defined as follows [6]:

- **Automobiles (A):** All vehicles having two axles and four tires and designated primarily for transportation of nine or fewer passengers, i.e., automobiles, or for transportation of cargo, i.e., light trucks. Generally, the gross vehicle weight is less than 4500 kg (9900 lb).
- **Medium Trucks (MT):** All cargo vehicles having two axles and six tires. Generally, the gross vehicle weight is greater than 4500 kg (9900 lb) but less than 12,000 kg (26,400 lb).
- **Heavy Trucks (HT):** All cargo vehicles having three or more axles. Generally, the gross vehicle weight is greater than 12,000 kg (26,400 lb).
- **Buses (B):** All vehicles having two or three axles and designated for transportation of nine or more passengers.
- **Motorcycles (MC):** All vehicles having two or three tires with an open-air driver and/or passenger compartment.

Vehicle distributions were provided in the traffic study in accordance with FHWA Scheme F classifications [7], which is typically used to categorize road use rather than vehicle noise. For the noise modeling, the Scheme F classifications data was converted into the TNM classifications described above, as shown in Table 3-1.

Table 3-1. Vehicle Classification Breakdown

TNM Class	Scheme F Class
A	2, 3
MT	5, 6 and 7
HT	8, 9
B	4
MC	1

Detailed traffic counts were conducted as part of the same traffic study to determine vehicle distributions at the three bridge crossings. Vehicle distributions were assumed to remain constant over the length of the road and throughout the duration of the project. Since vehicle distribution data was not provided in the traffic study for the roads other than Florida Ave., N. Claiborne Ave. and St. Claude Ave., engineering judgment was used to estimate vehicle distribution on the arterial roads. Roadway ADT and vehicle distribution by Type is shown in Table 3-2.

Table 3-2. Roadway ADT and Vehicle Distribution by Type

Roadway	ADT	A (%)	MT (%)	HT (%)	B (%)	MC (%)
Florida Ave.	976	66	18	11	4	1
N. Claiborne Ave.	19,558	78	10	10	1	1
St. Claude Ave.	11,474	83	10	5	1	1
Arterial Roads	-	98	1	1	0	0

As provided in the traffic study, the traffic volumes were additionally sub-divided into time segments within the day for the following break-down:

AM (0600-0900);

MD (0901-1600);

PM (1601-1900); and

NT (1901-0559).

The noise analysis was performed using the DNL metric, which includes sound energy exposure for day (0700-2200) and night (2201-0659), with a 10-decibel penalty for nighttime noise events. Traffic volumes by day (D) and night (N) were converted from the traffic study break-down as follows:

D = 2/3 AM + MD + PM + 3/11 NT; and

N = 1/3 AM + 8/11 NT.

Since overall ADT is the same for each sub-division, the DNL as a daily average noise metric incorporates the total daily traffic volumes for all roadways.

3.2 Railway Traffic

Two railroad lines are in proximity to the IHNC. The New Orleans Public Belt Railroad runs parallel to the west bank of the IHNC. The Norfolk-Southern Railroad runs perpendicular to the IHNC at the north opening along Florida Ave. Both railroads are shown as red lines in Figure 3-2.

It was assumed that railway traffic would remain constant over the duration of the project. Existing railway traffic data was collected and provided by Gulf South Research Corporation (GSRC) and listed in Table 3-3. An existing rail yard is located on the west bank of the IHNC next to the proposed lock location.

Table 3-3. Daily Railway Traffic Data

Railroad	Public Belt	Public Belt	Norfolk Southern
Direction	West	East	West
Locomotives	1 to 3	1	1
Daytime Trips	14	2	2
Nighttime Trips	4	2	1
Freight cars/train	57	57	40
Track	Welded	Welded	Welded
Speed (mph)	10	10	10
Whistle Stop	At crossings, bridge, Florida Ave	At crossings	At crossings, bridge, Florida Ave.
Power	Diesel	Diesel	Diesel
Grade	None	None	None

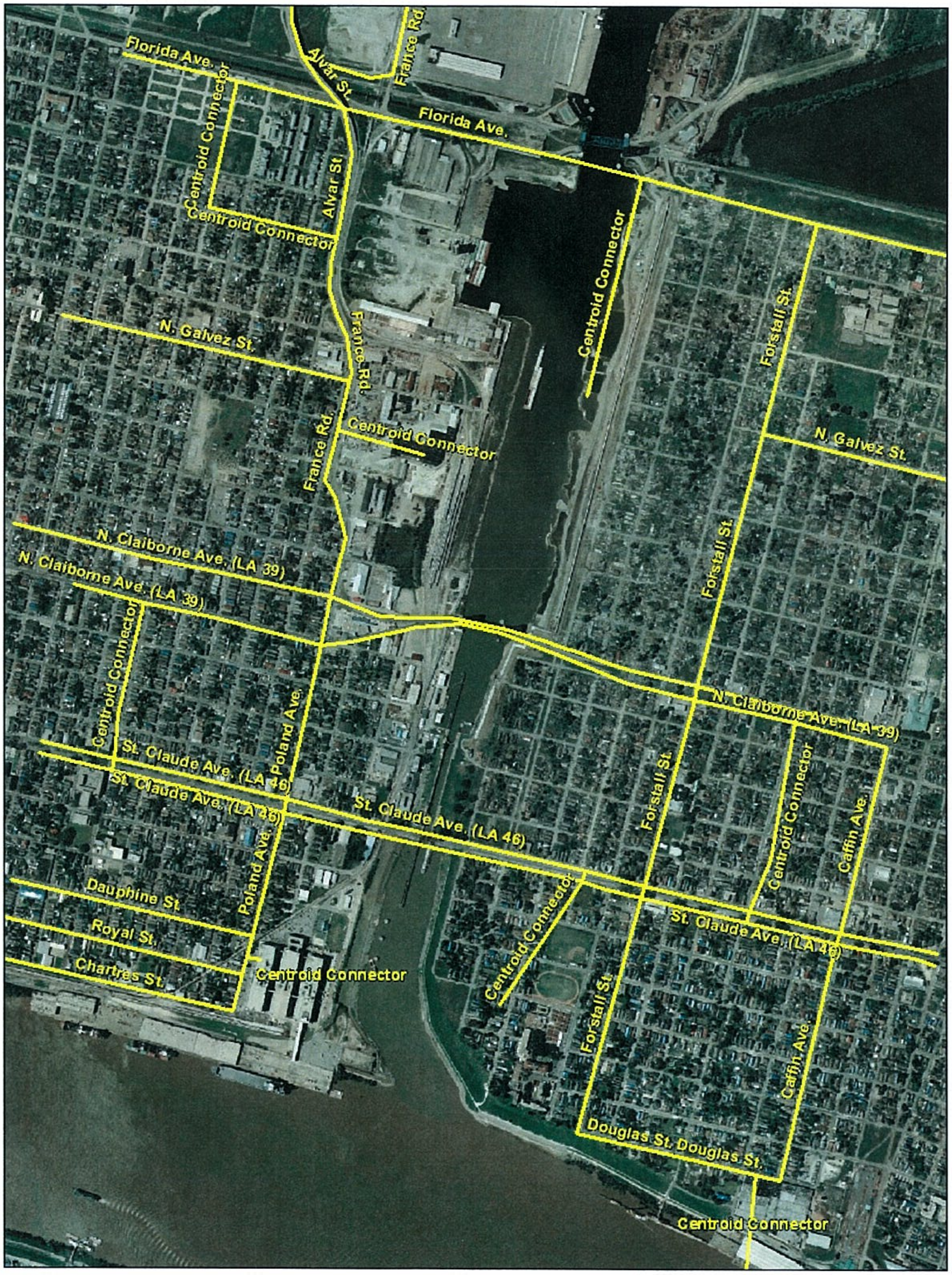

Figure 3-1. Major Roadways within the Project Site

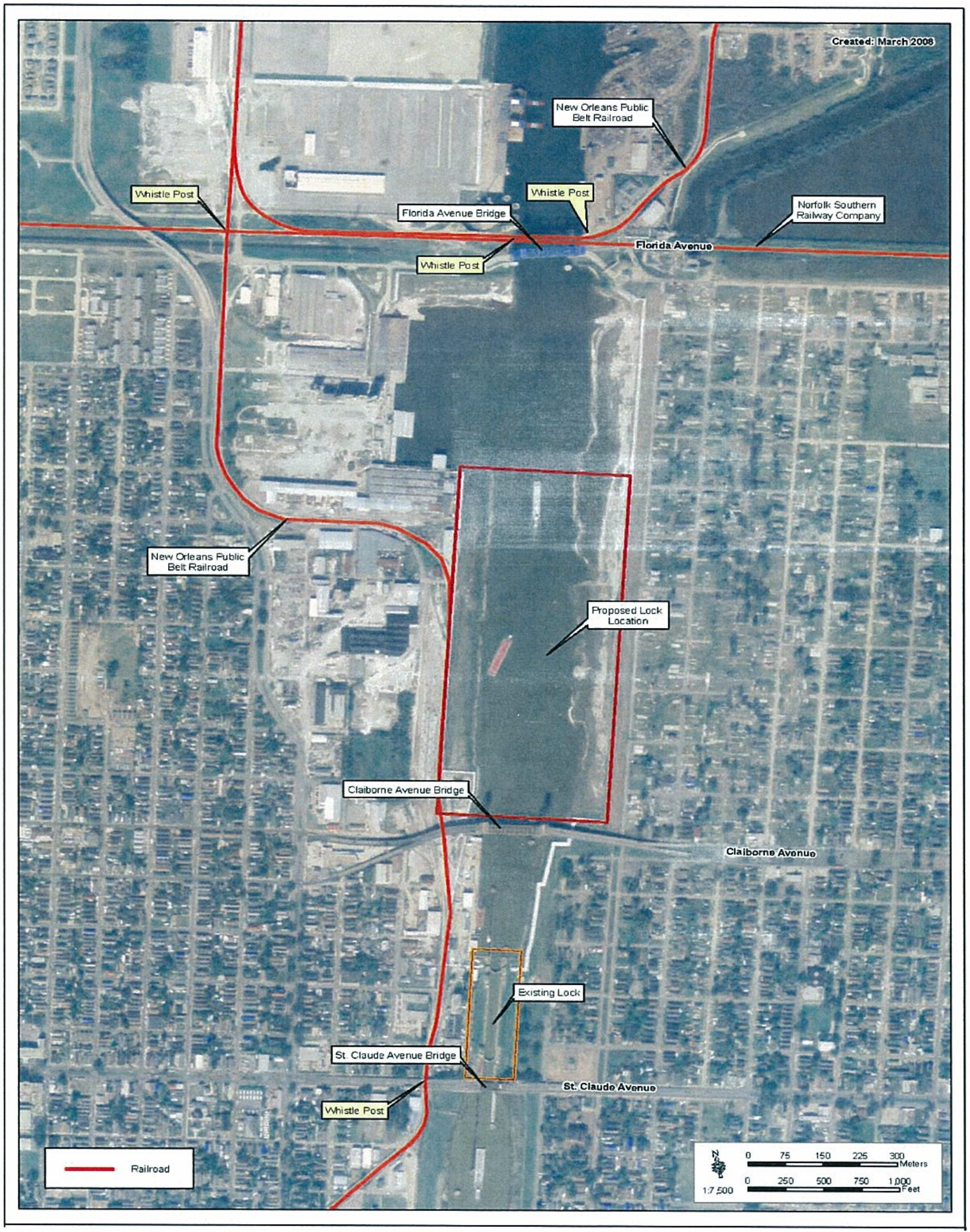

Figure 3-2. Railroad Track Locations

4.0 Construction Noise Sources

The replacement lock for the IHNC is to be built north of the Claiborne Ave. Bridge, between Claiborne Ave. and N. Tonti St. The construction area is denoted in red line in Figure 4-1. Construction equipment used during the lock replacement will include: vibratory and impact hammer pile drivers, dredging pumps, dump trucks, cement mixers, and batch plant operations. A batch plant is a temporary or portable cement production facility, typically consisting of cement mixing equipment and several silos for the cement ingredients. The construction of the new lock and removal of the existing lock is expected to last over 10 years. Pile driving operations will occur over most of that duration throughout the construction site.

Construction noise impacts were assessed for a daily noise exposure based on a 10-hour work shift during daytime hours. Since exact location and timeframes are not known, the sound energy for each construction noise source was distributed uniformly over the entire construction area. The resulting noise level contours are representative of average daily noise level during various construction scenarios modeled. The scenarios are detailed in Chapter 6.0. If construction activity is concentrated in one particular area during a certain time period, then noise levels would increase in the proximity of that location and decrease in other areas. Therefore, the actual noise levels during construction could be higher or lower than the calculated DNL values on a day-to-day basis.

4.1 Pile Driving Operations

Piles will be driven for either the float-in-place (FIP) or cast-in-place (CIP) lock construction methods in several locations throughout the construction area. The piles will form part of the protective cells, guide wall, lock foundation, and coffer dam for the CIP lock. According to the proposed construction timeline, pile driving operations will occur for the most of the project duration. Pile driving is the loudest construction noise source.

It was estimated that the average daily noise contour would be approximately equivalent for either FIP or CIP lock construction. Fewer piles will be driven for the FIP method than the CIP method; however, piles will be driven in many of the same locations within the construction area. The significant difference, in terms of pile driving operations, is that a coffer dam will be built for the CIP but not the FIP and the protective cells at the north opening of the lock would be removed and replaced for each of the four lock modules floated-in. The coffer dam would consist of sheet piles around the perimeter of the proposed lock. The protective cells are 78 feet in diameter and consist of multiple piles driven in close proximity. Beyond these differences other piles required for the total project are similar. The total duration of pile driving operations for FIP will be approximately nine months shorter than for CIP [8]; however, the noise contours will remain approximately the same for an average day during either CIP or FIP construction. It is expected that public response will favor FIP due to shorter total duration.

Vibratory and impact hammer pile drivers will be used in the construction of the replacement lock. It is typical for vibratory hammers to start the pile and drive it to a specified depth and then an impact hammer drives the pile to the final depth. For this analysis it was assumed that the vibratory and impact hammers would be used in this manner. It was assumed that two such systems would be in operation simultaneously on the construction site. The noise source for pile driving was assumed at a height of 16.4 ft (5 m) above the water level.

Vibratory hammers are treated as a continuous noise source, while impact hammers are an impulsive noise source. The sound pressure level at specified distance is given in [9] for both vibratory and impact hammers. The value is 101 dB at 50 feet and is equivalent for both pile driver types. This value converted in the sound power level, results in L_W of 97 dB. Adding a second source is equivalent to doubling the sound power, which results in a 3 dB increase in the sound power level. An octave band spectrum for a typical vibratory hammer is shown in Table 4-1. The strike of an impact hammer is impulsive in nature. Therefore it was modeled as a broadband noise source.

Table 4-1. Typical Vibratory Hammer Pile Driver Octave Band Spectrum

Octave Band (Hz)	63	125	250	500	1000	2000	4000
Sound Power Level (dB)	81	87	93	95	93	87	81

* SoundPLAN Library, Taschenbuch der Technischen Akustik,1994

It was assumed that the vibratory hammer would be in operation 20% for every hour during the working day. The impact hammer was assumed to operate at a rate of 900 blows or impulses per hour during the working day. This is a typical rate equivalent to one blow every four seconds as determined in [10] and supported by the USACE measurement results during pile driving tests at the proposed replacement lock site [11]. The working day for the constrained construction schedule is specified as 10 hours during daylight hours.

4.2 Dredging Operations

Dredging operations are scheduled for eleven dredge material management units (DMMUs) along the length of the IHNC. The DMMUs can be seen in Figure 4-2. It was assumed that dredging operations will consist of a diesel engine supplying power to the dredging pump located 1 meter above water level on a barge. The diesel engine will be the dominant noise contributor. The barge will move throughout each DMMU over the duration of the dredging process. The typical diesel engine generator octave band spectrum is shown in Table 4-2.

Table 4-2. Typical Diesel Engine Generator Octave Band Spectrum

Octave Band (Hz)	63	125	250	500	1000	2000	4000
Sound Power Level (dB)	68.8	78.9	86.4	91.8	95.0	96.2	96.0

* SoundPLAN Library, General noise Prediction Guideline ÖAL 28, Published by the Austrian Noise Control Association

4.3 Batch Plant Operations

A batch plant will be constructed for concrete production at the general construction site. According to the USACE Noise and Vibrations Monitoring report [11], the general construction site is located in an one-city block area on the east bank of IHNC between N. Johnson St. and N. Galvez St. Dump and cement truck traffic will travel along an access road on the east bank of the IHNC between Florida Ave. and the general construction site. The typical noise source spectra for batch plant operations are listed in Table 4-3. Typical cement mixing operations have a sound power level of 110 dB at the 500 Hz octave band frequency.

Table 4-3. Batch Plant Operations Sound Power Octave Band Spectra Level (dB)

Octave Band (Hz)	63	125	250	500	1000	2000	4000
Heavy Truck Traffic	44.0	59.7	61.5	65.0	69.2	68.0	63.0
Unloading Dump Truck	91.5	95.5	99.5	102.5	105.5	103.5	98.5

* SoundPLAN Library, General noise Prediction Guideline ÖAL Industry Guideline No. 111, Hessische Landesanstalt für Umwelt, 16.05.1995

Figure 4-1. Construction Site of Proposed IHNC Replacement Lock

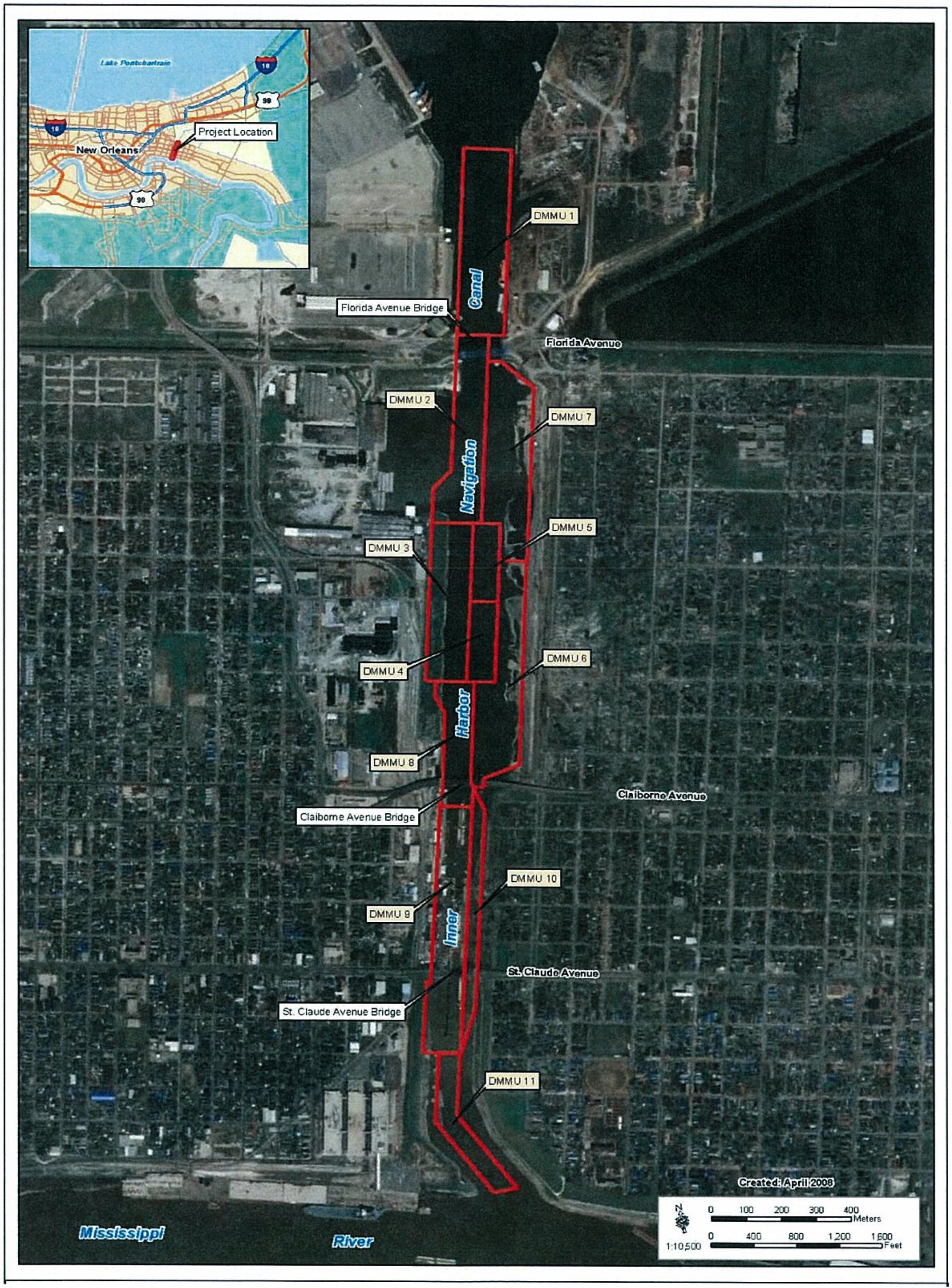

Figure 4-2. Dredge Material Management Units (DMMU)

5.0 Noise Modeling Approach

The SoundPLAN noise prediction software [12] was used to model construction and traffic noise impacts. The following recognized and accepted standards were used in the algorithm: ISO 9613-2 [13] for industrial noise, Federal Highway Administration (FHWA) Traffic Noise Model (TNM) version 2.5 [14] for traffic noise and NORD2000 [15] for ground effects and atmospheric absorption.

All noise sources (roadway traffic, railway traffic and construction activities) detailed above were incorporated in the SoundPLAN model for the entire project site. The project site was considered to include all land for 3000 feet on either side of the IHNC. This would be the area between Caffin Ave. (east of the IHNC) and Independence St. (west of the IHNC). SoundPLAN utilizes a ray-tracing algorithm to calculate the overall DNL from all noise sources at grid points over the entire project site. A grid noise map was generated for 50 ft (15 m) grid spacing. This spacing optimizes resolution with the model calculation time. The noise maps calculated for various conditions of the project are provided and discussed in the next chapter.

The project site spans nearly a three square mile area. Due to the size and number of buildings within that area, each residential city-block was modeled as a building mitigation area with one row of one-story buildings facing major noise sources. This approach simplifies the model calculation time yet retains realistic noise level reduction due to shielding and scattering from houses within the city-block. Larger buildings such as schools and industrial buildings were modeled as solid structures.

A flood wall or levee surrounds the perimeter of the IHNC extending from the north opening of the existing lock beyond Florida Ave. to the north. The current height of the flood wall is 12 ft (3.7 m) except between N. Claiborne Ave. and Florida Ave. on the east side of the IHNC where the height is 15 ft (4.6 m). The flood wall will provide some shielding for the construction noise because most construction activity will occur on the canal-side of the flood wall, below its top edge. The flood wall was modeled as a concrete barrier and is shown in Figures 6-1 through 6-5 as a solid grey line.

Minor noise sources were considered negligible and omitted from the analysis. Meteorological effects due to wind or extreme temperatures were not considered in this analysis. Demolition was assumed to be short in duration such that it does not influence the DNL contours over the total duration of the project. Barge movements and tugboat operations were assumed negligible noise contributors.

6.0 Noise Modeling Results

Grid noise maps were calculated for five scenarios to determine the average DNL contours:

- No Action plan with existing (2008) vehicle traffic (Plan 1);
- Plan 3 with existing (2008) vehicle traffic;
- Plan 3 with detour enacted (2014 vehicle traffic) for N. Claiborne Ave. Bridge replacement;
- Plan 3 post N. Claiborne Ave. Bridge replacement with 2014 vehicle traffic; and
- Post IHNC lock construction with future (2038) vehicle traffic.

Plan 3 is a revision to the 1997 EIS lock replacement plan. Since the preparation of the 1997 EIS, portions of the originally proposed project and additional studies, design and analyses have been completed that require a revision to the original lock replacement plan. Most of these changes involve details associated with dredged material reuse and disposal. However, in addition to the original proposed FIP construction method evaluated in the 1997 EIS, a second plan that would allow for CIP construction has been evaluated. The CIP lock construction including revisions from the 1997 EIS is termed Plan 3a and the FIP lock construction including revisions is termed Plan 3b. As described above, acoustically Plan 3a and 3b will be approximately equivalent for the duration of construction. For this reason, the noise modeling results are presented in terms of Plan 3, which include both lock construction methods.

As indicated in Chapter 1.0, the DNL of 65 dB of below are compatible with residential land use. The noise contour map for the No Action plan (Plan 1) is shown Figure 6-1.

For this scenario with no construction activities, roadway traffic is the major noise source. It can be seen in Figure 6-1 that the DNL 65 contour due to traffic intersects the first city block on either side of Florida Ave., N. Claiborne Ave., St. Claude Ave., France Rd., Poland Ave., and Chartes St. Vehicle traffic crossing the N. Claiborne Ave. Bridge is a significant noise contributor due to the traffic volume, particularly trucks, height of the bridge and open metal grid road deck.

For Plan 3, construction and dredging noise sources in the construction area were incorporated in the noise model. The noise contour map for Plan 3 with existing (2008) traffic is shown in Figure 6-2.

It can be seen in Figure 6-2 that the DNL 65 contour is significantly increased due to construction activities in the IHNC construction area. To the east of the IHNC the DNL 65 contour extends as far as Forstall St. north of N. Claiborne Ave and Jourdan Ave. between N. Claiborne Ave. and N. Villere St. To the west of the IHNC, the residential areas are mostly shielded by industrial buildings and the resulting noise levels are no greater than the No Action Plan, except for the two city blocks of Poland Ave. north of N. Claiborne Ave.

Residential areas approximately between Tennessee St., Jourdan Ave., N. Prieur St., and N. Miro St. are within the DNL 75 contour. According to HUD these levels are unacceptable and severe to both indoor and outdoor activities.

The N. Claiborne Ave. Bridge is currently planned to be replaced in 2014. The bridge replacement is expected to last up to six months. During that time vehicle traffic will detour from N. Claiborne Ave. to Florida Ave., significantly increasing the vehicle traffic on Florida Ave. The noise contour map for the N. Claiborne Ave. detour (2014 traffic) with continuing construction of the IHNC replacement lock is shown in Figure 6-3.

As can be seen in Figure 6-3, the DNL 65 contour expands predominately along Florida Ave. encompassing nearly an entire city block to the south. As expected, noise levels decrease in the proximity of the N. Claiborne Ave. Bridge and significantly along N. Claiborne Ave. east of the IHNC due to the bridge closure.

After the N. Claiborne Ave. Bridge is replaced, the detour will be removed and construction will begin on the temporary bridge along St. Claude Ave. Piles will be driven for the temporary bridge. The noise contour map for post N. Claiborne Ave. Bridge replacement (2014 traffic) and pile driving for temporary bridge along St. Claude Ave. is shown in Figure 6-4.

As can be seen in Figure 6-4, the DNL 65 contour recedes along Florida Ave. The additional pile driving for the temporary bridge causes the DNL 65 contour to expand to Jourdan Ave. between N. Claiborne Ave. and N. Rampart St.

The noise contour map for future (2038) traffic volumes is shown in Figure 6-5. It is expected that construction of the IHNC replacement lock will be completed by that time. Construction noise sources are not incorporated for this modeling scenario. Comparison of the existing 2008 traffic noise contours (Figure 6-1) with the future 2038 traffic noise contours (Figure 6-5) indicates that noise levels will significantly increase in the future due to increased traffic volumes.

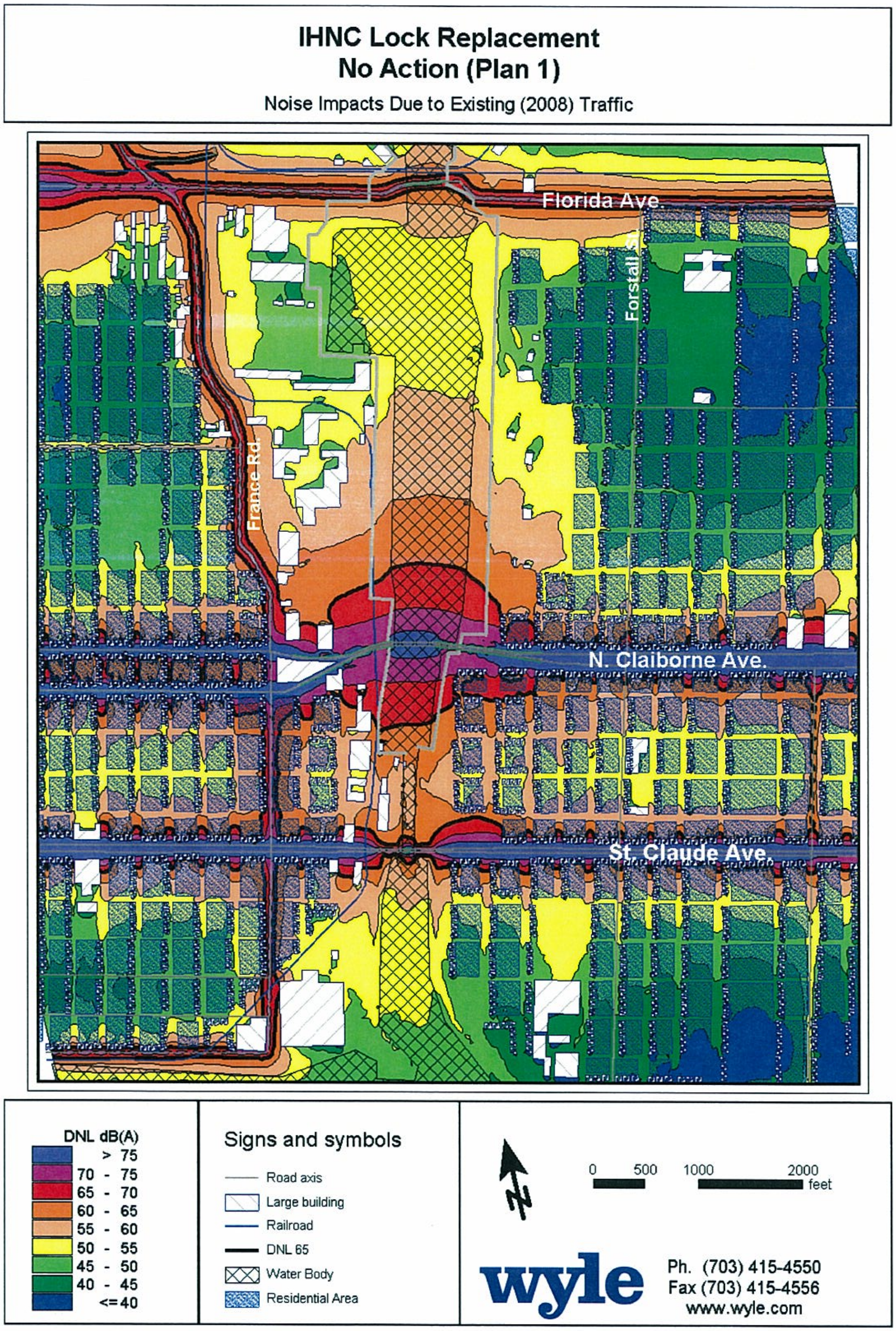

Figure 6-1. No Action Existing DNL Noise Contours

Figure 6-2. DNL Noise Contours Due to Construction and Existing Traffic

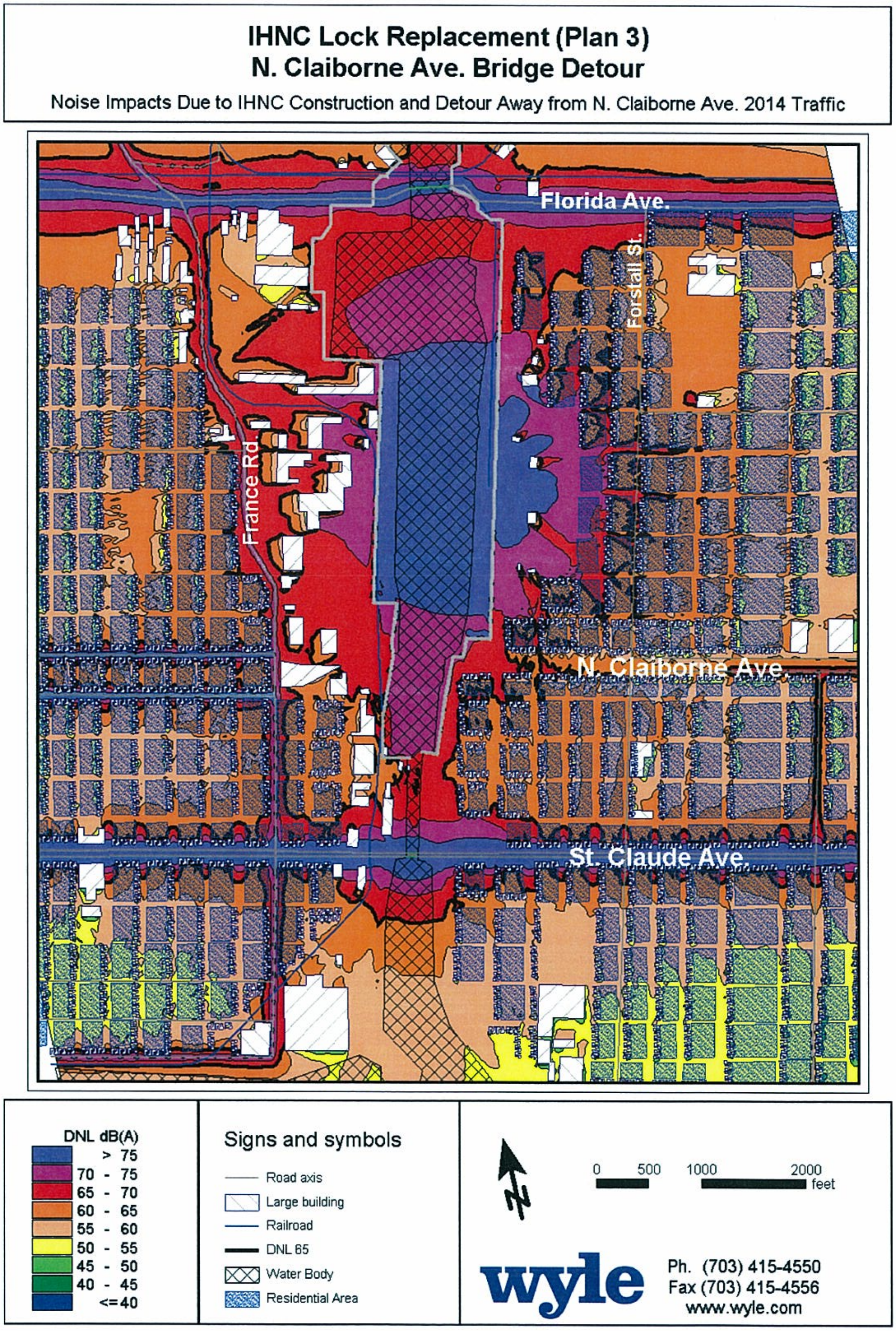

Figure 6-3. DNL Noise Contours Due to Construction and N. Claiborne Ave. Detour

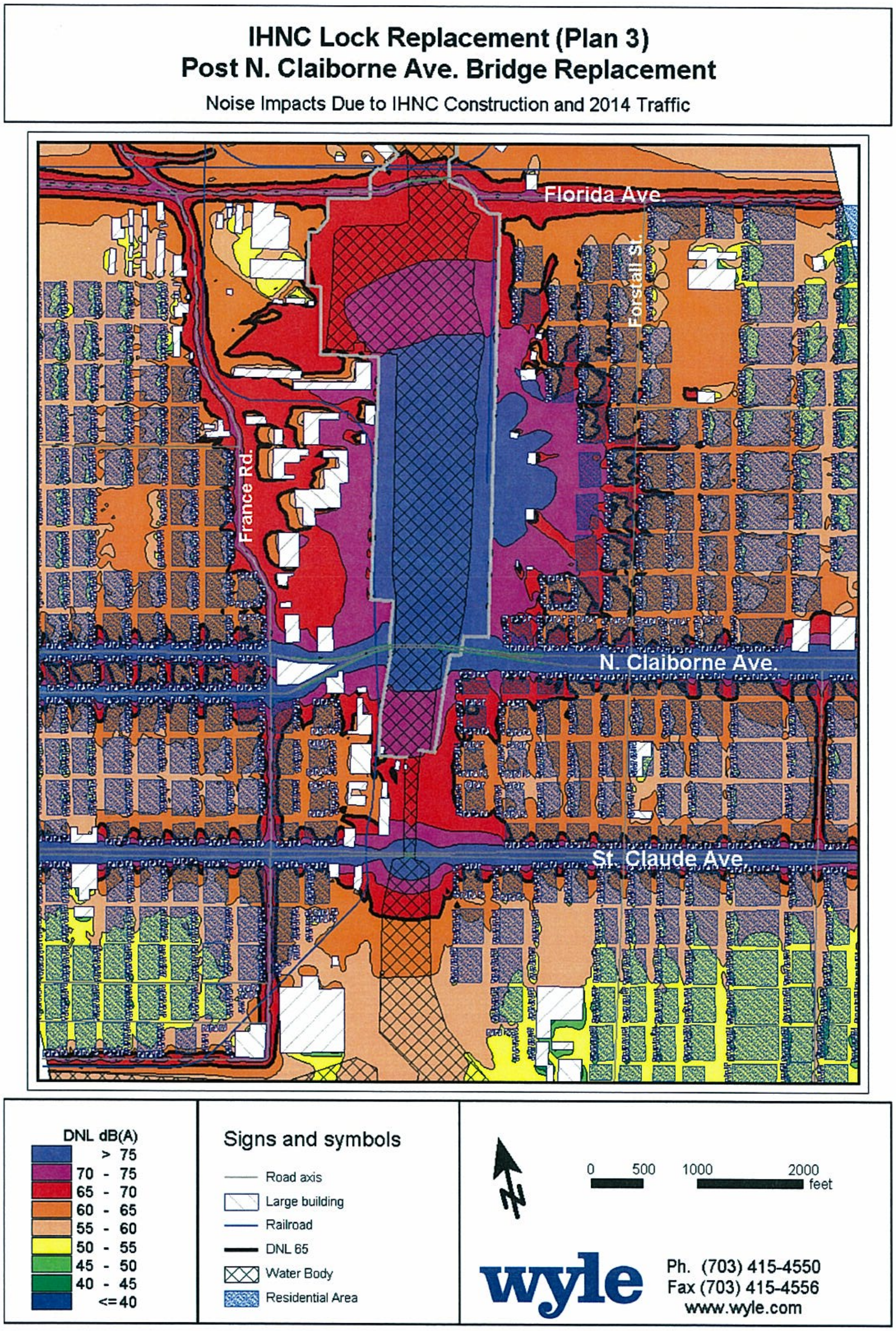

Figure 6-4. DNL Contours Due to Construction and 2014 Traffic Post N. Claiborne Ave. Bridge Replacement

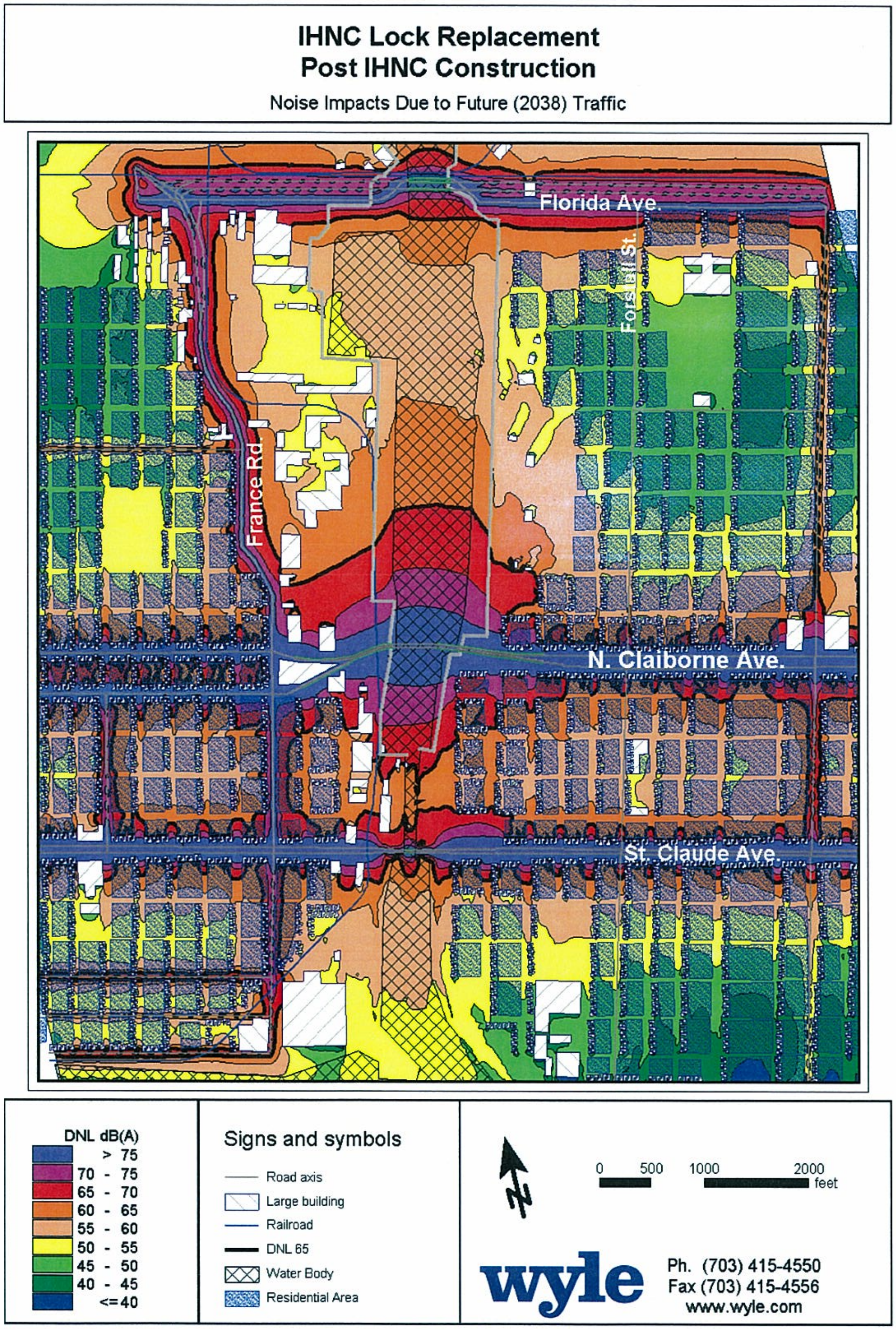

Figure 6-5. DNL Contours Due to Future (2038) Traffic Post IHNC Lock Construction

7.0 Construction Vibration Impacts

Vibration impacts from construction activities and pile driving operations were assessed in the vicinity of the construction site based on the vibration measurement data provided in [11] and summarized in [16]. This limited vibration monitoring data was collected for the background conditions (no construction activities), general construction with no pile driving activities, and pile driving activities with an impact hammer (hydraulic or air hammer) or vibratory hammer. The vibration measurements were conducted at various distances from 100 to 1000 ft from the center of jobsite (between flood walls of the canal).

It was determined that the measured average maximum peak particle velocity values varied primarily between 0.02 and 0.1 in/s, with the maximum readings of 0.15 in/s. The vibration average frequencies during the monitoring varied between 15 and 30 Hz. It was also concluded that the peak particle velocities during all pile driving operations did not exceed the values measured for the background or general construction conditions.

In the following, these results were evaluated with respect to reaction of humans to vibrations in buildings as provided in ANSI standard [17]. A multiplying factor of 0.71 was applied to the peak particle velocity values indicated above for the impulsive vibration, to convert those into the right-mean-square (rms) magnitudes used in the standard. The corresponding frequency-weighting according to the standard was then applied to the measurement data using the appropriate attenuation factor for the frequency range indicated above. The resulting frequency-weighted rms particle velocity values vary in the range from approximately 2.4×10^{-3} to 2.4×10^{-2} in/s (6×10^{-5} to 6×10^{-4} m/s), with the maximum values reaching 3.5×10^{-2} in/s (9×10^{-4} m/s).

The standard provides a basic rating for satisfactory vibration magnitudes for humans within buildings. The base-response curve used corresponds to the approximate threshold of vibration perception of the most-sensitive humans. It is specified for a frequency range from 1 to 80 Hz. The recommended vibration magnitudes are given for the most-stringent conditions and are such that there is no possibility of human fatigue or other vibration-induced symptoms. For assessment of human reaction to whole-body vibration inside buildings, the standard base-response curve was adjusted using a multiplication factor according to the location of the receiver, building type and other specific conditions. The multiplying factor of 4 is used for residential buildings during daytime and office buildings at all times. The adjusted base-response curve represents recommended satisfactory magnitudes with respect to human response to vibration in buildings. For the frequency range of interest between 15 and 30 Hz, the adjusted base-response curve value is 1.6×10^{-2} in/s (4×10^{-4} m/s) for the rms velocity. Vibration magnitudes exceeding this adjusted base-response curve value are considered likely to generate adverse human reactions.

The vibration monitoring used in this analysis was performed outside buildings. The existing standards recognize such measurements, but do not recommend specific values for possible amplification describing transformation of ground-borne vibrations to structural vibration inside a building. Adjustment factors between unity and four have been suggested in some research. Since most of the buildings in the study area are of a typical one- and two-story residential and school construction (not tall buildings), it is appropriate for the purpose of the analysis to assume no significant vibration amplification inside the buildings.

Comparison of the measured frequency-weighted rms particle velocity values ($2.4x10^{-3}$ to $2.4x10^{-2}$ in/s with the maximum of $3.5x10^{-2}$ in/s, as described above), with the standard recommended adjusted base-response value ($1.6x10^{-2}$ in/s) shows that the lower range of the measured vibrations is under the acceptable vibration value. Vibrations with such velocities will not be perceptible by people. However, vibrations with velocities in the upper measured range, especially at the maximum value, exceed the acceptable level, will be perceptible to people and will possibly generate adverse reactions.

The measurement data, referred to above, also indicated that the general construction vibration at the upper limit of the range was measured up to a distance of 850 ft from the center of the jobsite. This infers that vibrations generated by construction activities during the project will be perceptible to residents within this distance from the general construction area, including the floodwalls on each side of the canal. The approximate limits of such an area are Tennessee St. to the east of the canal and Poland Av. to the west.

With regards to potential adverse impact of the ground-borne vibration on buildings and structures, an rms velocity of 0.5 in/s (0.013 m/s) is often considered as a safe limit, and minor structural damage (glass and plaster cracks) may begin to occur at 2.0 in/s (0.05 m/s). These vibration velocity structural damage values exceed the standard range of acceptable vibration levels with respect to human response, indicated above, by at least an order of magnitude. As concluded in [11], the results of the vibration measurements were well below the structural damage threshold level. Therefore, the proposed construction activities or pile driving will not adversely impact any structure or building in the vicinity of the construction site outside the floodwalls.

8.0 Conclusions

Noise analysis was conducted for roadway and railway traffic and all significant construction noise sources for the IHNC lock replacement project. Several scenarios were modeled including: No Action (Plan 1) with existing (2008) traffic, IHNC construction with existing (2008) traffic, IHNC construction and Florida Ave detour due to N. Claiborne Ave. Bridge replacement with 2014 traffic, IHNC construction post N. Claiborne Ave. Bridge replacement with 2014 traffic, and post IHNC construction (no construction) with future (2038) traffic. The noise analysis is presented in terms of the day-night average sound level (DNL), following the HUD guidelines for land-use compatibility. Computer-generated noise maps for each modeling scenario are provided with the report. The following conclusions can be made from the analysis:

DNL levels will exceed HUD allowable levels (DNL 65 dB) in several residential areas due to construction of the IHNC lock and related traffic detours.

In particular, residential areas to the east of the IHNC (Lower 9th Ward) will be most impacted by construction noise during the lock replacement. The DNL 65 contour extends as far as Forstall St. and the DNL 75 contour extends as far as Tennessee St. to the east of the IHNC for both roads north of N. Claiborne Ave. According to HUD, DNL above 65 dB is considered normally unacceptable and DNL above 75 dB is considered unacceptable for residential areas.

It is recommended that an acoustical consultant be retained to provide mitigation solutions to affected residential areas and noise-sensitive buildings.

Comparison of existing (2008) and future (2038) roadway traffic noise levels indicate that noise levels are expected to increase significantly due to the projected increase of vehicular traffic volumes.

Limited vibration measurement data from a previous study [11] was analyzed and compared with applicable standards on human and structural response to vibration. The following conclusions can be made from the analysis:

Vibration levels due to both general construction activities and pile driving operations are expected to exceed human perception thresholds at low frequencies for distances up to 850 ft the construction site.

Perceptible vibration of structures and rattle of elements within buildings is likely for residences within three city-blocks of the IHNC construction area.

Construction activities or pile driving will not adversely impact any structure of building in the vicinity of the construction site outside the floodwalls.

To determine detailed vibration exposure contours, it is recommended that additional vibration measurements and spectral analysis be conducted for general construction activities and pile driving.

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APPENDIX A

Discussion of Noise and Its Effect on the Environment

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Discussion of Noise and Its Effect on the Environment

A.1 Basics of Sound

Noise is unwanted sound. Sound is all around us; sound becomes noise when it interferes with normal activities, such as sleep or conversation.

Sound is a physical phenomenon consisting of minute vibrations that travel through a medium, such as air, and are sensed by the human ear. Whether that sound is interpreted as pleasant (e.g., music) or unpleasant (e.g., jackhammers) depends largely on the listener's current activity, past experience, and attitude toward the source of that sound.

The measurement and human perception of sound involves three basic physical characteristics: intensity, frequency, and duration. First, intensity is a measure of the acoustic energy of the sound vibrations and is expressed in terms of sound pressure. The greater the sound pressure, the more energy carried by the sound and the louder the perception of that sound. The second important physical characteristic of sound is frequency, which is the number of times per second the air vibrates or oscillates. Low-frequency sounds are characterized as rumbles or roars, while high-frequency sounds are typified by sirens or screeches. The third important characteristic of sound is duration or the length of time the sound can be detected.

The loudest sounds that can be detected comfortably by the human ear have intensities that are a trillion times higher than those of sounds that can barely be detected. Because of this vast range, using a linear scale to represent the intensity of sound becomes very unwieldy. As a result, a logarithmic unit known as the decibel (abbreviated dB) is used to represent the intensity of a sound. Such a representation is called a sound level. A sound level of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions. Normal speech has a sound level of approximately 60 dB; sound levels above 120 dB begin to be felt inside the human ear as discomfort. Sound levels between 130 to 140 dB are felt as pain (Berglund and Lindvall 1995).

Because of the logarithmic nature of the decibel unit, sound levels cannot be arithmetically added or subtracted and are somewhat cumbersome to handle mathematically. However, some simple rules are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. For example:

60 dB + 60 dB = 63 dB, and

80 dB + 80 dB = 83 dB.

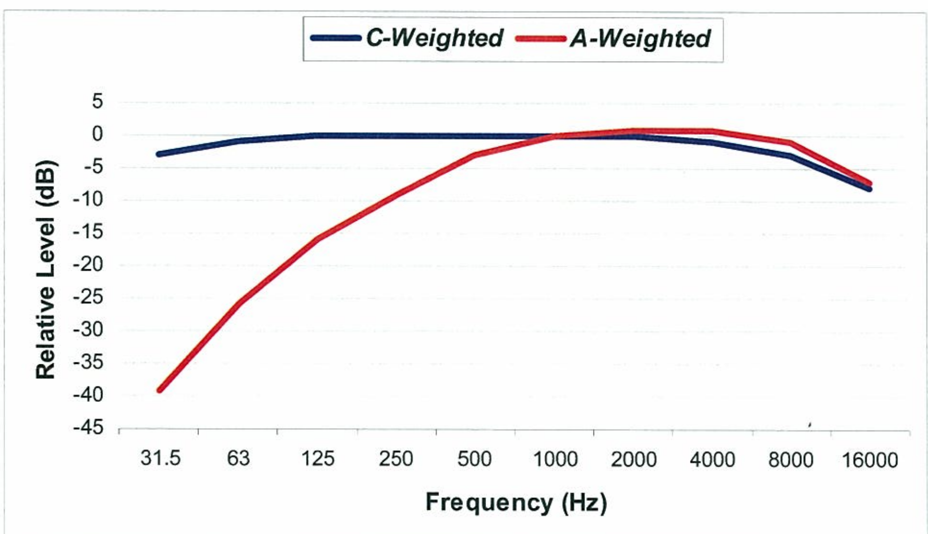
Second, the total sound level produced by two sounds of different levels is usually only slightly more than the higher of the two. For example:

60.0 dB + 70.0 dB = 70.4 dB.

Because the addition of sound levels is different than that of ordinary numbers, such addition is often referred to as "decibel addition" or "energy addition." The latter term arises from the fact that what we are really doing when we add decibel values is first converting each decibel value to its corresponding acoustic energy, then adding the energies using the normal rules of addition, and finally converting the total energy back to its decibel equivalent.

The minimum change in the sound level of individual events that an average human ear can detect is about 3 dB. On average, a person perceives a change in sound level of about 10 dB as a doubling (or halving) of the sound's loudness, and this relation holds true for loud and quiet sounds. A decrease in sound level of 10 dB actually represents a 90% decrease in sound intensity but only a 50% decrease in perceived loudness because of the nonlinear response of the human ear (similar to most human senses).

Sound frequency is measured in terms of cycles per second (cps), or hertz (Hz), which is the standard unit for cps. The normal human ear can detect sounds that range in frequency from about 20 Hz to about 15,000 Hz. All sounds in this wide range of frequencies, however, are not heard equally by the human ear, which is most sensitive to frequencies in the 1,000 to 4,000 Hz range. Weighting curves have been developed to correspond to the sensitivity and perception of different types of sound. A-weighting and C-weighting are the two most common weightings. A-weighting accounts for frequency dependence by adjusting the very high and very low frequencies (below approximately 500 Hz and above approximately 10,000 Hz) to approximate the human ear's lower sensitivities to those frequencies. C-weighting is nearly flat throughout the range of audible frequencies, hardly de-emphasizing the low frequency sound while approximating the human ear's sensitivity to higher intensity sounds. The two curves shown in Figure A-1 are also the most adequate to quantify environmental noises.



Source: ANSI S1.4 -1983 "Specification of Sound Level Meters"

Figure A-1. Frequency Response Characteristics of A and C Weighting Networks

A.1.2 A-weighted Sound Level

Sound levels that are measured using A-weighting, called A-weighted sound levels, are often denoted by the unit dBA or dB(A) rather than dB. When the use of A-weighting is understood, the adjective "A-weighted" is often omitted and the measurements are expressed as dB. In this report (as in most environmental impact documents), dB units refer to A-weighted sound levels.

Noise potentially becomes an issue when its intensity exceeds the ambient or background sound pressures. Ambient background noise in metropolitan, urbanized areas typically varies from 60 to 70 B and can be as high as 80 dB or greater; quiet suburban neighborhoods experience ambient noise levels of approximately 45-50 dB (U.S. Environmental Protection Agency 1978).

Figure A-2 is a chart of A-weighted sound levels from typical sounds. Some noise sources (air conditioner, vacuum cleaner) are continuous sounds which levels are constant for some time. Some (automobile, heavy truck) are the maximum sound during a vehicle pass-by. Some (urban daytime, urban nighttime) are averages over extended periods. A variety of noise metrics have been developed to describe noise over different time periods, as discussed below.

Aircraft noise consists of two major types of sound events: aircraft takeoffs and landings, and engine maintenance operations. The former can be described as intermittent sounds and the latter as continuous. Noise levels from flight operations exceeding background noise typically occur beneath main approach and departure corridors, in local air traffic patterns around the airfield, and in areas immediately adjacent to parking ramps and aircraft staging areas. As aircraft in flight gain altitude, their noise contribution drops to lower levels, often becoming indistinguishable from the background.

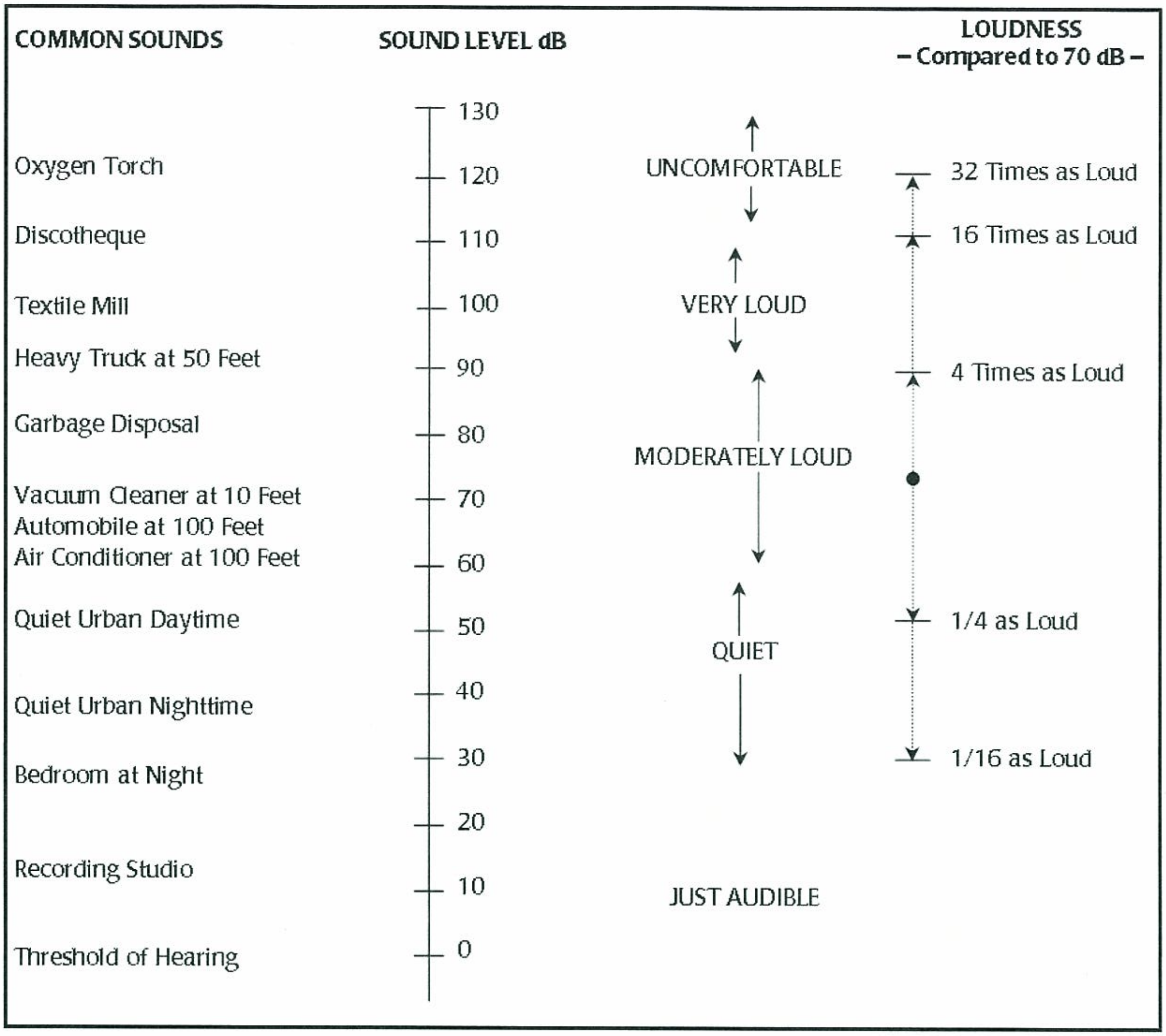
C-weighted Sound Level

Sound levels measured using a C-weighting are most appropriately called C-weighted sound levels (and denoted dBC). C-weighting is nearly flat throughout the audible frequency range, hardly de-mphasizing the low frequency. This weighting scale is generally used to describe impulsive sounds. Sounds that are characterized as impulsive generally contain low frequencies. Impulsive sounds may induce secondary effects, such as shaking of a structure, rattling of windows, inducing vibrations. These secondary effects can cause additional annoyance and complaints.

The following definitions in the American National Standard Institute (ANSI) Report S12.9, Part 4 provide general concepts helpful in understanding impulsive sounds (American National Standards Institute 1996).

Impulsive Sound: Sound characterized by brief excursions of sound pressure (acoustic impulses) that significantly exceeds the ambient environmental sound pressure. The duration of a single impulsive sound is usually less than one second (American National Standards Institute 1996).

Highly Impulsive Sound: Sound from one of the following enumerated categories of sound sources: small-arms gunfire, metal hammering, wood hammering, drop hammering, pile driving, drop forging, pneumatic hammering, pavement breaking, metal impacts during rail-yard shunting operation, and riveting.



Source: *Handbook of Noise Control*, C.M. Harris, Editor, McGraw-Hill Book Co., 1979, and FICAN 1992.

Figure A-2. Typical A-weighted Sound Levels of Common Sounds

<u>High-energy Impulsive Sound</u>: Sound from one of the following enumerated categories of sound sources: quarry and mining explosions, sonic booms, demolition and industrial processes that use high explosives, military ordnance (e.g., armor, artillery and mortar fire, and bombs), explosive ignition of rockets and missiles, explosive industrial circuit breakers, and any other explosive source where the equivalent mass of dynamite exceeds 25 grams.

A.2 Noise Metrics

As used in environmental noise analyses, a metric refers to the unit or quantity that quantitatively measures the effect of noise on the environment. To quantify these effects, the Department of Defense and the Federal Aviation Administration use three noise-measuring techniques, or metrics: first, a measure of the highest sound level occurring during an individual aircraft overflight (single event); second, a combination of the maximum level of that single event with its duration; and third, a description of the noise environment based on the cumulative flight and engine maintenance activity. Single noise events can be described with Sound Exposure Level or Maximum Sound Level. Another measure of instantaneous level is the Peak Sound Pressure Level. The cumulative energy noise metric used is the Day/Night Average Sound Level. Metrics related to DNL include the Onset-Rate Adjusted Day/Night Average Sound Level, and the Equivalent Sound Level. In the state of California, it is mandated that average noise be described in terms of Community Noise Equivalent Level (State of California 1990). CNEL represents the Day/Evening/Night average noise exposure, calculated over a 24-hour period. Metrics and their uses are described below.

A.2.1 Maximum Sound Level (L_{max})

The highest A-weighted integrated sound level measured during a single event in which the sound level changes value with time (e.g., an aircraft overflight) is called the maximum A-weighted sound level or maximum sound level.

During an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft flies closest to the observer, and returns to the background level as the aircraft recedes into the distance. The maximum sound level indicates the maximum sound level occurring for a fraction of a second. For aircraft noise, the "fraction of a second" over which the maximum level is defined is generally 1/8 second, and is denoted as "fast" response (American National Standards Institute 1988). Slowly varying or steady sounds are generally measured over a period of one second, denoted "slow" response. The maximum sound level is important in judging the interference caused by a noise event with conversation, TV or radio listening, sleep, or other common activities. Although it provides some measure of the intrusiveness of the event, it does not completely describe the total event, because it does not include the period of time that the sound is heard.

A.2.2 Peak Sound Pressure Level (L_{pk})

The peak sound pressure level, is the highest instantaneous level obtained by a sound level measurement device. The peak sound pressure level is typically measured using a 20 microseconds or faster sampling rate, and is typically based on unweighted or linear response of the meter.

A.2.3 Sound Exposure Level (SEL)

Sound exposure level is a composite metric that represents both the intensity of a sound and its duration. Individual time-varying noise events (e.g., aircraft overflights) have two main characteristics: a sound level that changes throughout the event and a period of time during which the event is heard. SEL provides a measure of the net impact of the entire acoustic event, but it does not directly represent the sound level heard at any given time. During an aircraft flyover, SEL would include both the maximum noise level and the lower noise levels produced during onset and recess periods of the overflight.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the sound level of a constant sound that would, in one second, generate the same acoustic energy as the actual time-varying noise event. For sound from aircraft overflights, which typically lasts more than one second, the SEL is usually greater than the L_{max} because an individual overflight takes seconds and the maximum sound level (L_{max}) occurs instantaneously. SEL represents the best metric to compare noise levels from overflights.

A.2.4 Day-Night Average Sound Level (DNL) and Community Noise Equivalent Level (CNEL)

Day-Night Average Sound Level and Community Noise Equivalent Level are composite metrics that account for SEL of all noise events in a 24-hour period. In order to account for increased human sensitivity to noise at night, a 10 dB penalty is applied to nighttime events (10:00 p.m. to 7:00 a.m. time period). A variant of the DNL, the CNEL level includes a 5-decibel penalty on noise during the 7:00 p.m. to 10:00 p.m. time period, and a 10-decibel penalty on noise during the 10:00 p.m. to 7:00 a.m. time period.

The above-described metrics are average quantities, mathematically representing the continuous A-weighted or C-weighted sound level that would be present if all of the variations in sound level that occur over a 24-hour period were smoothed out so as to contain the same total sound energy. These composite metrics account for the maximum noise levels, the duration of the events (sorties or operations), and the number of events that occur over a 24-hour period. Like SEL, neither DNL nor CNEL represent the sound level heard at any particular time, but quantifies the total sound energy received. While it is normalized as an average, it represents all of the sound energy, and is therefore a cumulative measure.

The penalties added to both the DNL and CNEL metrics account for the added intrusiveness of sounds that occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours.

The inclusion of daytime and nighttime periods in the computation of the DNL and CNEL reflects their basic 24-hour definition. It can, however, be applied over periods of multiple days. For application to civil airports, where operations are consistent from day to day, DNL and CNEL are usually applied as an annual average. For some military airbases, where operations are not necessarily consistent from day to day, a common practice is to compute a 24-hour DNL or CNEL based on an average busy day, so that the calculated noise is not diluted by periods of low activity.

Although DNL and CNEL provide a single measure of overall noise impact, they do not provide specific information on the number of noise events or the individual sound levels that occur during the 24-hour day. For example, a daily average sound level of 65 dB could result from a very few noisy events or a large number of quieter events.

Daily average sound levels are typically used for the evaluation of community noise effects (i.e., long-term annoyance), and particularly aircraft noise effects. In general, scientific studies and social surveys have found a high correlation between the percentages of groups of people highly annoyed and the level of average noise exposure measured in DNL (U.S. Environmental Protection Agency 1978 and Schultz 1978). The correlation from Schultz's original 1978 study is shown in Figure A-3. It represents the results of a large number of social surveys relating community responses to various types of noises, measured in day-night average sound level.

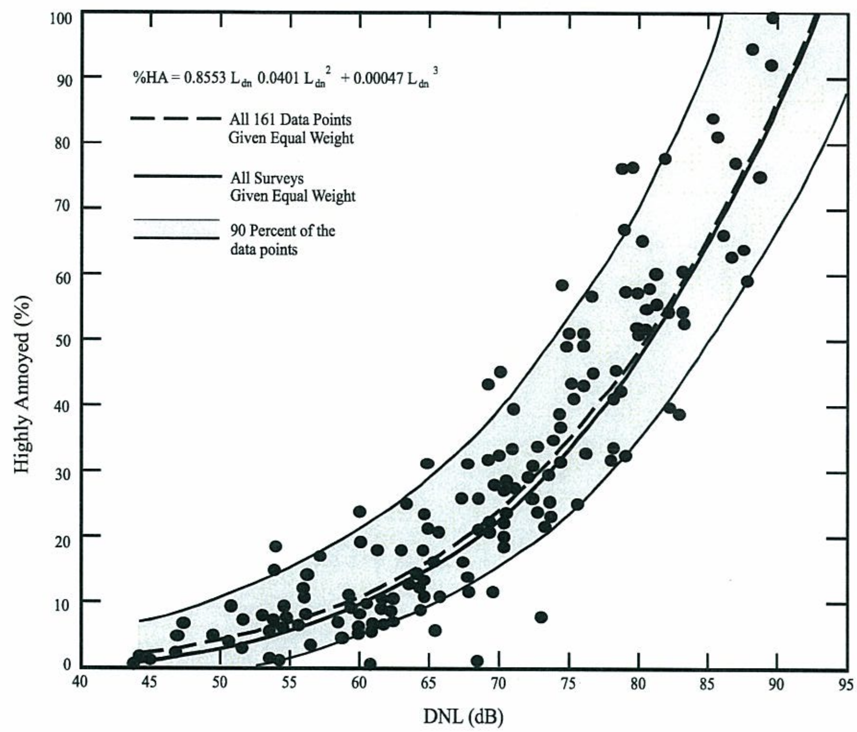


Figure A-3. Community Surveys of Noise Annoyance

A more recent study has reaffirmed this relationship (Fidell, et al. 1991). Figure A-4 (Federal Interagency Committee On Noise 1992) shows an updated form of the curve fit (Finegold, et al. 1994) in comparison with the original. The updated fit, which does not differ substantially from the original, is the current preferred form. In general, correlation coefficients of 0.85 to 0.95 are found between the percentages of groups of people highly annoyed and the level of average noise exposure. The correlation coefficients for the annoyance of individuals are relatively low, however, on the order of 0.5 or less. This is not surprising, considering the varying personal factors that influence the manner in which individuals react to noise. However, for the evaluation of community noise impacts, the scientific community has endorsed the use of DNL (American National Standards Institute 1980; American National Standards Institute 1988; U.S. Environmental Protection Agency 1974; Federal Interagency Committee On Urban Noise 1980 and Federal Interagency Committee On Noise 1992).

The use of DNL (CNEL in California) has been criticized as not accurately representing community annoyance and land-use compatibility with aircraft noise. Much of that criticism stems from a lack of understanding of the basis for the measurement or calculation of DNL. One frequent criticism is based on the inherent feeling that people react more to single noise events and not as much to "meaningless" time-average sound levels.

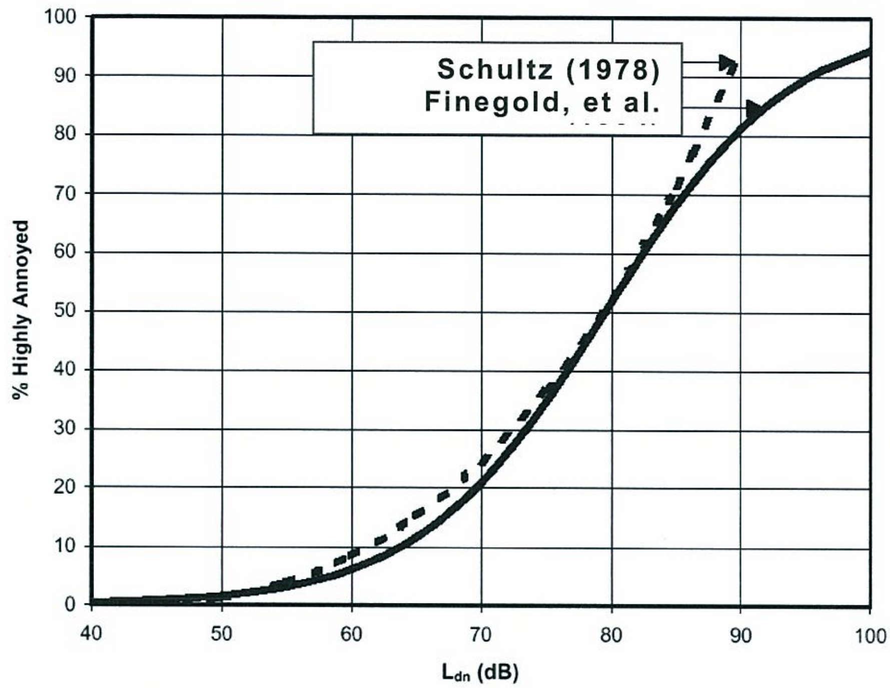


Figure A-4. Response of Communities to Noise; Comparison of Original (Schultz, 1978) and Current (Finegold, et al. 1994) Curve Fits

In fact, a time-average noise metric, such as DNL and CNEL, takes into account both the noise levels of all individual events that occur during a 24-hour period and the number of times those events occur. The logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average.

As a simple example of this characteristic, consider a case in which only one aircraft overflight occurs during the daytime over a 24-hour period, creating a sound level of 100 dB for 30 seconds. During the remaining 23 hours, 59 minutes, and 30 seconds of the day, the ambient sound level is 50 dB. The day-night average sound level for this 24-hour period is 65.9 dB. Assume, as a second example, that 10 such 30-second overflights occur during daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes of the day. The day-night average sound level for this 24-hour period is 75.5 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events and tends to emphasize both the sound levels and number of those events.

A.2.5 Equivalent Sound Level (L_{eq})

Another cumulative noise metric that is useful in describing noise is the equivalent sound level. L_{eq} is calculated to determine the steady-state noise level over a specified time period. The L_{eq} metric can provide a more accurate quantification of noise exposure for a specific period, particularly for daytime periods when the nighttime penalty under the DNL metric is inappropriate.

Just as SEL has proven to be a good measure of the noise impact of a single event, L_{eq} has been established to be a good measure of the impact of a series of events during a given time period. Also, while L_{eq} is defined as an average, it is effectively a sum over that time period and is, thus, a measure of the cumulative impact of noise. For example, the sum of all noise-generating events during the period of 7 a.m. to 4 p.m. could provide the relative impact of noise generating events for a school day.

A.2.6 Rate Adjusted Day-Night Average Sound Level (L_{dnr})

Military aircraft flying on Military Training Routes (MTRs) and in Restricted Areas/Ranges generate a noise environment that is somewhat different from that associated with airfield operations. As opposed to patterned or continuous noise environments associated with airfields, overflights along MTRs are highly sporadic, ranging from 10 per hour to less than one per week. Individual military overflight events also differ from typical community noise events in that noise from a low-altitude, high-airspeed flyover can have a rather sudden onset, exhibiting a rate of increase in sound level (onset rate) of up to 150 dB per second.

To represent these differences, the conventional SEL metric is adjusted to account for the "surprise" effect of the sudden onset of aircraft noise events on humans with an adjustment ranging up to 11 dB above the normal Sound Exposure Level (Stusnick, et al. 1992). Onset rates between 15 to 150 dB per second require an adjustment of 0 to 11 dB, while onset rates below 15 dB per second require no adjustment. The adjusted SEL is designated as the onset-rate adjusted sound exposure level (SEL_r).

Because of the sporadic, often seasonal, occurrences of aircraft overflights along MTRs and in Restricted Areas/Ranges, the number of daily operations is determined from the number of flying days in the calendar month with the highest number of operations in the affected airspace or MTR. This avoids dilution of the exposure from periods of low activity, much the way that the average busy day is used around military airbases. The cumulative exposure to noise in these areas is computed by DNL over the busy month, but using SEL_r instead of SEL. This monthly average is denoted L_{dnmr}. If onset rate adjusted DNL is computed over a period other than a month, it would be designated L_{dnr} and the period must be specified. In the state of California, a variant of the L_{dnmr} includes a penalty for evening operations (7 p.m. to 10 p.m) and is denoted $CNEL_{mr}$.

A.3 Noise Effects

A.3.1 Annoyance

The primary effect of aircraft noise on exposed communities is one of long-term annoyance. Noise annoyance is defined by the EPA as any negative subjective reaction on the part of an individual or group (U.S. Environmental Protection Agency 1974). As noted in the discussion of DNL above, community annoyance is best measured by that metric.

The results of attitudinal surveys, conducted to find percentages of people who express various degrees of annoyance when exposed to different levels of DNL, are very consistent. The most useful metric for assessing people's responses to noise impacts is the percentage of the exposed population expected to be "highly annoyed." A wide variety of responses have been used to determine intrusiveness of noise and disturbances of speech, sleep, television or radio listening, and outdoor living. The concept of "percent highly annoyed" has provided the most consistent response of a community to a particular noise environment. The response is remarkably complex, and when considered on an individual basis, widely varies for any given noise level (Federal Interagency Committee On Noise 1992).

A number of nonacoustic factors have been identified that may influence the annoyance response of an individual. Newman and Beattie (1985) divided these factors into emotional and physical variables:

Emotional Variables

- Feelings about the necessity or preventability of the noise;
- Judgment of the importance and value of the activity that is producing the noise;
- Activity at the time an individual hears the noise;
- Attitude about the environment;
- General sensitivity to noise;
- Belief about the effect of noise on health; and
- Feeling of fear associated with the noise.

Physical Variables

- Type of neighborhood;
- Time of day;
- Season;
- Predictability of noise;
- Control over the noise source; and
- Length of time an individual is exposed to a noise.

A.3.2 Speech Interference

Speech interference associated with aircraft noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities such as radio or television listening, telephone use, or family conversation gives rise to frustration and irritation. The quality of speech communication is also important in classrooms, offices, and industrial settings and can cause fatigue and vocal strain in those who attempt to communicate over the noise. Speech is an acoustic signal characterized by rapid fluctuations in sound level and frequency pattern. It is essential for optimum speech intelligibility to recognize these continually shifting sound patterns. Not only does noise diminish the ability to perceive the auditory signal, but it also reduces a listener's ability to follow the pattern of signal fluctuation. In general, interference with speech communication occurs when intrusive noise exceeds about 60 dB (Federal Interagency Committee On Noise 1992).

Indoor speech interference can be expressed as a percentage of sentence intelligibility among two people speaking in relaxed conversation approximately 3 feet apart in a typical living room or bedroom (U.S. Environmental Protection Agency 1974). The percentage of sentence intelligibility is a non-linear function of the (steady) indoor background A-weighted sound level. Such a curve-fit yields 100 percent sentence intelligibility for background levels below 57 dB and yields less than 10 percent intelligibility for background levels above 73 dB. The function is especially sensitive to changes in sound level between 65 dB and 75 dB. As an example of the sensitivity, a 1 dB increase in background sound level from 70 dB to 71 dB yields a 14 percent decrease in sentence intelligibility. The sensitivity of speech interference to noise at 65 dB and above is consistent with the criterion of DNL 65 dB generally taken from the Schultz curve. This is consistent with the observation that speech interference is the primary cause of annoyance.

A.3.3 Sleep Interference

Sleep interference is another source of annoyance and potential health concern associated with aircraft noise. Because of the intermittent nature and content of aircraft noise, it is more disturbing than continuous noise of equal energy. Given that quality sleep is requisite for good health, repeated occurrences of sleep interference could have an effect on overall health.

Sleep interference may be measured in either of two ways. "Arousal" represents actual awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without actual awakening. In general, arousal requires a somewhat higher noise level than does a change in sleep stage.

Sleep is not a continuous, uniform condition but a complex series of states through which the brain progresses in a cyclical pattern. Arousal from sleep is a function of a number of factors that include age, sex, sleep stage, noise level, frequency of noise occurrences, noise quality, and pre-sleep activity. Because individuals differ in their physiology, behavior, habitation, and ability to adapt to noise, few studies have attempted to establish noise criterion levels for sleep disturbance.

Lukas (1978) concluded the following with regard to human sleep response to noise:

- Children 5 to 8 years of age are generally unaffected by noise during sleep.
- Older people are more sensitive to sleep disturbance than younger people.
- Women are more sensitive to noise than men, in general.
- There is a wide variation in the sensitivity of individuals to noise even within the same age group.
- Sleep arousal is directly proportional to the sound intensity of aircraft flyover. While there have been several studies conducted to assess the effect of aircraft noise on sleep, none have produced quantitative dose-response relationships in terms of noise exposure level, DNL, and sleep disturbance. Noise-sleep disturbance relationships have been developed based on single-event noise exposure.

An analysis sponsored by the U.S. Air Force summarized 21 published studies concerning the effects of noise on sleep (Pearsons, et al. 1989). The analysis concluded that a lack of reliable studies in homes, combined with large differences among the results from the various laboratory studies, did not permit development of an acceptably accurate assessment procedure. The noise events used in the laboratory studies and in contrived in-home studies were presented at much higher rates of occurrence than would normally be experienced in the home. None of the laboratory studies were of sufficiently long duration to determine any effects of habituation, such as that which would occur under normal community conditions.

A study of the effects of nighttime noise exposure on the in-home sleep of residents near one military airbase, near one civil airport, and in several households with negligible nighttime aircraft noise exposure, revealed SEL as the best noise metric predicting noise-related awakenings. It also determined that out of 930 subject nights, the average spontaneous (not noise-related) awakenings per night was 2.07 compared to the average number of noise-related awakenings per night of 0.24 (Fidell, et al. 1994). Additionally, a 1995 analysis of sleep disturbance studies conducted both in the laboratory environment and in the field (in the sleeping quarters of homes) showed that when measuring awakening to noise, a 10 dB increase in SEL was associated with only an 8 percent increase in the probability of awakening in the laboratory studies, but only a 1 percent increase in the field (Pearsons, et al. 1995). Pearsons, et al. (1995), reported that even SEL values as high as 85 dB produced no awakenings or arousals in at least one study. This observation suggests a strong influence of habituation on susceptibility to noise-induced sleep disturbance. A 1984 study (Kryter 1984) indicates that an indoor SEL of 65 dB or lower should awaken less than 5 percent of exposed individuals.

Nevertheless, some guidance is available in judging sleep interference. The EPA identified an indoor DNL of 45 dB as necessary to protect against sleep interference (U.S. Environmental Protection Agency 1978). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor day-night average sound level of 65 dB to minimize sleep interference.

In 1997, the Federal Interagency Committee on Aviation Noise (FICAN) adopted an interim guideline for sleep awakening prediction. The new curve, based on studies in England (Ollerhead, et al. 1992) and at two U.S. airports (Los Angeles International and Denver International), concluded that the incidence of sleep awakening from aircraft noise was less than identified in a 1992 study (Federal Interagency Committee On Noise 1992). Using indoor single-event noise levels represented by SEL, potential sleep awakening can be predicted using the curve presented in Figure A-5. Typically, homes in the United States provide 15 dB of sound attenuation with windows open and 25 dB with windows closed and air conditioning operating. Hence, the outdoor SEL of 107 dB would be 92 dB indoors with windows open and 82 dB indoors with windows closed and air conditioning operating.

Using Figure A-5, the potential sleep awakening would be 15% with windows open and 10% with windows closed in the above example.

The new FICAN curve does not address habituation over time by sleeping subjects and is applicable only to adult populations. Nevertheless, this curve provides a reasonable guideline for assessing sleep awakening. It is conservative, representing the upper envelope of field study results.

The FICAN curve shown in Figure A-5 represents awakenings from single events. To date, no exact quantitative dose-response relationship exists for noise-related sleep interference from multiple events; yet, based on studies conducted to date and the USEPA guideline of a 45 DNL to protect sleep interference, useful ways to assess sleep interference have emerged. If homes are conservatively estimated to have a 20-dB noise insulation, an average of 65 DNL would produce an indoor level of 45 DNL and would form a reasonable guideline for evaluating sleep interference. This also corresponds well to the general guideline for assessing speech interference. Annoyance that may result from sleep disturbance is accounted for in the calculation of DNL, which includes a 10-dB penalty for each sortie occurring after 10 pm or before 7 am.

A.3.4 Hearing Loss

Considerable data on hearing loss have been collected and analyzed. It has been well established that continuous exposure to high noise levels will damage human hearing (U.S. Environmental Protection Agency 1978). People are normally capable of hearing up to 120 dB over a wide frequency range. Hearing loss is generally interpreted as the shifting of a higher sound level of the ear's sensitivity or acuity to perceive sound. This change can either be temporary, called a temporary threshold shift (TTS), or permanent, called a permanent threshold shift (PTS) (Berger, et al. 1995).

The EPA has established 75 dB for an 8-hour exposure and 70 dB for a 24-hour exposure as the average noise level standard requisite to protect 96% of the population from greater than a 5 dB PTS (U.S. Environmental Protection Agency 1978). Similarly, the National Academy of Sciences Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) identified 75 dB as the minimum level at which hearing loss may occur (Committee on Hearing, Bioacoustics, and Biomechanics 1977). However, it is important to note that continuous, long-term (40 years) exposure is assumed by both EPA and CHABA before hearing loss may occur.

Federal workplace standards for protection from hearing loss allow a time-average level of 90 dB over an 8-hour work period or 85 dB over a 16-hour period. Even the most protective criterion (no measurable hearing loss for the most sensitive portion of the population at the ear's most sensitive frequency, 4,000 Hz, after a 40-year exposure) is a time-average sound level of 70 dB over a 24-hour period.

Studies on community hearing loss from exposure to aircraft flyovers near airports showed that there is no danger, under normal circumstances, of hearing loss due to aircraft noise (Newman and Beattie 1985).

A laboratory study measured changes in human hearing from noise representative of low-flying aircraft on MTRs. (Nixon, et al. 1993). In this study, participants were first subjected to four overflight noise exposures at A-weighted levels of 115 dB to 130 dB. One-half of the subjects showed no change in hearing levels, one-fourth had a temporary 5-dB increase in sensitivity (the people could hear a 5-dB wider range of sound than before exposure), and one-fourth had a temporary 5-dB decrease in sensitivity (the people could hear a 5-dB narrower range of sound than before exposure). In the next phase, participants were subjected to a single overflight at a maximum level of 130 dB for eight successive exposures, separated by 90 seconds or until a temporary shift in hearing was observed. The temporary hearing threshold shifts resulted in the participants hearing a wider range of sound, but within 10 dB of their original range.

In another study of 115 test subjects between 18 and 50 years old, temporary threshold shifts were measured after laboratory exposure to military low-altitude flight (MLAF) noise (Ising, et al. 1999). According to the authors, the results indicate that repeated exposure to MLAF noise with L_{max} greater than 114 dB, especially if the noise level increases rapidly, may have the potential to cause noise induced hearing loss in humans.

Because it is unlikely that airport neighbors will remain outside their homes 24 hours per day for extended periods of time, there is little possibility of hearing loss below a day-night average sound level of 75 dB, and this level is extremely conservative.

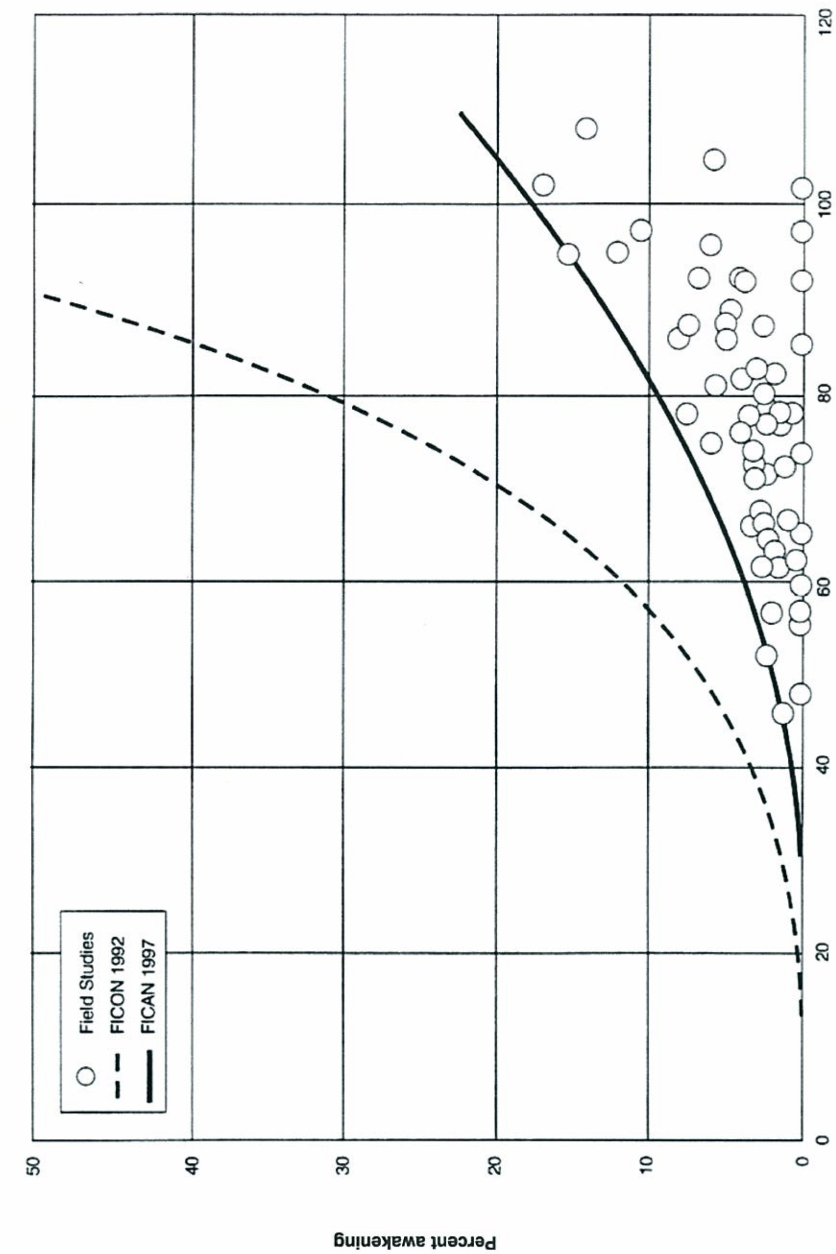


Figure A-5. Recommended Sleep Disturbance Dose-Response Relationship

A.3.5 Non-auditory Health Effects

Studies have been conducted to determine whether correlations exist between noise exposure and cardiovascular problems, birth weight, and mortality rates. The non-auditory effect of noise on humans is not as easily substantiated as the effect on hearing. The results of studies conducted in the United States, primarily concentrating on cardiovascular response to noise, have been contradictory (Cantrell 1974). Cantrell (1974) concluded that the results of human and animal experiments show that average or intrusive noise can act as a stress-provoking stimulus. Prolonged stress is known to be a contributor to a number of health disorders. Kryter and Poza (1980) state, "It is more likely that noise-related general ill-health effects are due to the psychological annoyance from the noise interfering with normal everyday behavior, than it is from the noise eliciting, because of its intensity, reflexive response in the autonomic or other physiological systems of the body." Psychological stresses may cause a physiological stress reaction that could result in impaired health.

The National Institute for Occupational Safety and Health and EPA commissioned CHABA in 1981 to study whether established noise standards are adequate to protect against health disorders other than hearing defects. CHABA's conclusion was that:

Evidence from available research reports is suggestive, but it does not provide definitive answers to the question of health effects, other than to the auditory system, of long-term exposure to noise. It seems prudent, therefore, in the absence of adequate knowledge as to whether or not noise can produce effects upon health other than damage to auditory system, either directly or mediated through stress, that insofar as feasible, an attempt should be made to obtain more critical evidence.

Since the CHABA report, there have been more recent studies that suggest that noise exposure may cause hypertension and other stress-related effects in adults. Near an airport in Stockholm, Sweden, the prevalence of hypertension was reportedly greater among nearby residents who were exposed to energy averaged noise levels exceeding 55 dB and maximum noise levels exceeding 72 dB, particularly older subjects and those not reporting impaired hearing ability (Rosenlund, et al. 2001). A study of elderly volunteers who were exposed to simulated military low-altitude flight noise reported that blood pressure was raised by L_{max} of 112 dB and high speed level increase (Michalak, et al. 1990). Yet another study of subjects exposed to varying levels of military aircraft or road noise found no significant relationship between noise level and blood pressure (Pulles, et al. 1990).

The U.S. Department of the Navy prepared a programmatic Environmental Assessment (EA) for the continued use of non-explosive ordnance on the Vieques Inner Range. Following the preparation of the EA, it was learned that research conducted by the University of Puerto Rico, Ponce School of Medicine, suggested that Vieques fishermen and their families were experiencing symptoms associated with vibroacoustic disease (VAD) (U.S. Department of the Navy 2002). The study alleged that exposure to noise and sound waves of large pressure amplitudes within lower frequency bands, associated with Navy training activities—specifically, air-to-ground bombing or naval fire support—was related to a larger prevalence of heart anomalies within the Vieques fishermen and their families. The Ponce School of Medicine study compared the Vieques group with a group from Ponce Playa. A 1999 study conducted on Portuguese aircraft-manufacturing workers from a single factory reported effects of jet aircraft noise exposure that involved a wide range of symptoms and disorders, including the cardiac issues on which the Ponce School of Medicine study focused. The 1999 study identified these effects as VAD.

Johns Hopkins University (JHU) conducted an independent review of the Ponce School of Medicine study, as well as the Portuguese aircraft workers study and other relevant scientific literature. Their findings concluded that VAD should not be accepted as a syndrome, given that exhaustive research across a number of populations has not yet been conducted. JHU also pointed out that the evidence supporting the existence of VAD comes largely from one group of investigators and that similar results would have to be replicated by other investigators. In short, JHU concluded that it had not been established that noise was the causal agent for the symptoms reported and no inference can be made as to the role of noise from naval gunfire in producing echocardiographic abnormalities (U.S. Department of the Navy 2002).

Most studies of non-auditory health effects of long-term noise exposure have found that noise exposure levels established for hearing protection will also protect against any potential non-auditory health effects, at least in workplace conditions. One of the best scientific summaries of these findings is contained in the lead paper at the National Institutes of Health Conference on Noise and Hearing Loss, held on 22 to 24 January 1990 in Washington, D.C.:

> "The non-auditory effects of chronic noise exposure, when noise is suspected to act as one of the risk factors in the development of hypertension, cardiovascular disease, and other nervous disorders, have never been proven to occur as chronic manifestations at levels below these criteria (an average of 75 dBA for complete protection against hearing loss for an 8-hour day). At the recent (1988) International Congress on Noise as a Public Health Problem, most studies attempting to clarify such health effects did not find them at levels below the criteria protective of noise-induced hearing loss, and even above these criteria, results regarding such health effects were ambiguous. Consequently, one comes to the conclusion that establishing and enforcing exposure levels protecting against noise-induced hearing loss would not only solve the noise-induced hearing loss problem, but also any potential non-auditory health effects in the work place" (von Gierke 1990).

Although these findings were specifically directed at noise effects in the workplace, they are equally applicable to aircraft noise effects in the community environment. Research studies regarding the non-auditory health effects of aircraft noise are ambiguous, at best, and often contradictory. Yet, even those studies that purport to find such health effects use time-average noise levels of 75 dB and higher for their research.

For example, two UCLA researchers apparently found a relationship between aircraft noise levels under the approach path to Los Angeles International Airport (LAX) and increased mortality rates among the exposed residents by using an average noise exposure level greater than 75 dB for the "noise-exposed" population (Meacham and Shaw 1979). Nevertheless, three other UCLA professors analyzed those same data and found no relationship between noise exposure and mortality rates (Frerichs, et al. 1980).

As a second example, two other UCLA researchers used this same population near LAX to show a higher rate of birth defects for 1970 to 1972 when compared with a control group residing away from the airport (Jones and Tauscher 1978). Based on this report, a separate group at the Center for Disease Control performed a more thorough study of populations near Atlanta's Hartsfield International Airport (ATL) for 1970 to 1972 and found no relationship in their study of 17 identified categories of birth defects to aircraft noise levels above 65 dB (Edmonds, et al. 1979).

In summary, there is no scientific basis for a claim that potential health effects exist for aircraft time-average sound levels below 75 dB.

The potential for noise to affect physiological health, such as the cardiovascular system, has been speculated; however, no unequivocal evidence exists to support such claims (Harris 1997). Conclusions drawn from a review of health effect studies involving military low-altitude flight noise with its unusually high maximum levels and rapid rise in sound level have shown no increase in cardiovascular disease (Schwartze and Thompson 1993). Additional claims that are unsupported include flyover noise producing increased mortality rates and increases in cardiovascular death, aggravation of post-traumatic stress syndrome, increased stress, increase in admissions to mental hospitals, and adverse affects on pregnant women and the unborn fetus (Harris 1997).

A.3.6 Performance Effects

The effect of noise on the performance of activities or tasks has been the subject of many studies. Some of these studies have established links between continuous high noise levels and performance loss. Noise-induced performance losses are most frequently reported in studies employing noise levels in excess of 85 dB. Little change has been found in low-noise cases. It has been cited that moderate noise levels appear to act as a stressor for more sensitive individuals performing a difficult psychomotor task.

While the results of research on the general effect of periodic aircraft noise on performance have yet to yield definitive criteria, several general trends have been noted including:

- A periodic intermittent noise is more likely to disrupt performance than a steady-state continuous noise of the same level. Flyover noise, due to its intermittent nature, might be more likely to disrupt performance than a steady-state noise of equal level.
- Noise is more inclined to affect the quality than the quantity of work.
- Noise is more likely to impair the performance of tasks that place extreme demands on the worker.

A.3.7 Noise Effects on Children

In response to noise-specific and other environmental studies, Executive Order 13045, Protection of Children from Environmental Health Risks and Safety Risks (1997), requires federal agencies to ensure that policies, programs, and activities address environmental health and safety risks to identify any disproportionate risks to children.

A review of the scientific literature indicates that there has not been a tremendous amount of research in the area of aircraft noise effects on children. The research reviewed does suggest that environments with sustained high background noise can have variable effects, including noise effects on learning and cognitive abilities, and reports of various noise-related physiological changes.

A3.7.1 Effects on Learning and Cognitive Abilities

In 2002 release of the "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools," the American National Standards Institute refers to studies that suggest that loud and frequent background noise can affect the learning patterns of young children. ANSI provides discussion on the relationships between noise and learning, and stipulates design requirements and acoustical performance criteria for outdoor-to-indoor noise isolation. School design is directed to be cognizant of, and responsive to, surrounding land uses and the shielding of outdoor noise from the indoor environment. ANSI has approved a new standard for acoustical performance criteria in schools. The new criteria include the requirement that the one-hour-average background noise level shall not exceed 35 dBA in core learning spaces smaller than 20,000 cubic-feet and 40 dBA in core learning spaces with enclosed volumes exceeding 20,000 cubic-feet. This would require schools be constructed such that, in quiet neighborhoods indoor noise levels are lowered by 15 to 20 dBA relative to outdoor levels. In schools near airports, indoor noise levels would have to be lowered by 35 to 45 dBA relative to outdoor levels (American National Standards Institute 2002).

The studies referenced by ANSI to support the new standard are not specific to jet aircraft noise and the potential effects on children. However, there are references to studies that have shown that children in noisier classrooms scored lower on a variety of tests. Excessive background noise or reverberation within schools causes interferences of communication and can therefore create an acoustical barrier to learning (American National Standards Institute 2002). Studies have been performed that contribute to the body of evidence emphasizing the importance of communication by way of the spoken language to the development of cognitive skills. The ability to read, write, comprehend, and maintain attentiveness, are, in part, based upon whether teacher communication is consistently intelligible (American National Standards Institute 2002).

Numerous studies have shown varying degrees of effects of noise on the reading comprehension, attentiveness, puzzle-solving, and memory/recall ability of children. It is generally accepted that young children are more susceptible than adults to the effects of background noise. Because of the developmental status of young children (linguistic, cognitive, and proficiency), barriers to hearing can cause interferences or disruptions in developmental evolution.

Research on the impacts of aircraft noise, and noise in general, on the cognitive abilities of school-aged children has received more attention in recent years. Several studies suggest that aircraft noise can affect the academic performance of schoolchildren. Although many factors could contribute to learning deficits in school-aged children (e.g., socioeconomic level, home environment, diet, sleep patterns), evidence exists that suggests that chronic exposure to high aircraft noise levels can impair learning.

Specifically, elementary school children attending schools near New York City's two airports demonstrated lower reading scores than children living farther away from the flight paths (Green, et al. 1982). Researchers have found that tasks involving central processing and language comprehension (such as reading, attention, problem solving, and memory) appear to be the most affected by noise (Evans and Lepore 1993; Hygge 1994; and Evans, et al. 1998). It has been demonstrated that chronic exposure of first- and second-grade children to aircraft noise can result in reading deficits and impaired speech perception (i.e., the ability to hear common, low-frequency [vowel] sounds but not high frequencies [consonants] in speech) (Evans and Maxwell 1997).

The Evans and Maxwell (1997) study found that chronic exposure to aircraft noise resulted in reading deficits and impaired speech perception for first- and second-grade children. Other studies found that children residing near the Los Angeles International Airport had more difficulty solving cognitive problems and did not perform as well as children from quieter schools in puzzle-solving and attentiveness (Bronzaft 1997; Cohen, et al. 1980). Children attending elementary schools in high aircraft noise areas near London's Heathrow Airport demonstrated poorer reading comprehension and selective cognitive impairments (Haines, et al. 2001a, and 2001b). Similarly, a study conducted by Hygge (1994) found that students exposed to aircraft noise (76 dBA) scored 20% lower on recall ability tests than students exposed to ambient noise (42-44 dBA). Similar studies involving the testing of attention, memory, and reading comprehension of schoolchildren located near airports showed that their tests exhibited reduced performance results compared to those of similar groups of children who were located in quieter environments (Evans, et al. 1998; Haines, et al. 1998). The Haines and Stansfeld study indicated that there may be some long-term effects associated with exposure, as one-year follow-up testing still demonstrated lowered scores for children in higher noise schools (Haines, et al. 2001a, and 2001b). In contrast, a study conducted by Hygge, et al. (2002) found that although children living near the old Munich airport scored lower in standardized reading and long-term memory tests than a control group, their performance on the same tests was equal to that of the control group once the airport was closed.

Finally, although it is recognized that there are many factors that could contribute to learning deficits in school-aged children, there is increasing awareness that chronic exposure to high aircraft noise levels may impair learning. This awareness has led the World Health Organization and a North Atlantic Treaty Organization working group to conclude that daycare centers and schools should not be located near major sources of noise, such as highways, airports, and industrial sites (World Health Organization 2000; North Atlantic Treaty Organization 2000).

A3.7.2 Health Effects

Physiological effects in children exposed to aircraft noise and the potential for health effects have also been the focus of limited investigation. Studies in the literature include examination of blood pressure levels, hormonal secretions, and hearing loss.

As a measure of stress response to aircraft noise, authors have looked at blood pressure readings to monitor children's health. Children who were chronically exposed to aircraft noise from a new airport near Munich, Germany, had modest (although significant) increases in blood pressure, significant increases in stress hormones, and a decline in quality of life (Evans, et al. 1998). Children attending noisy schools had statistically significant average systolic and diastolic blood pressure ($p<0.03$). Systolic blood pressure means were 89.68 mm for children attending schools located in noisier environments compared to 86.77 mm for a control group. Similarly, diastolic blood pressure means for the noisier environment group were 47.84 mm and 45.16 for the control group (Cohen, et al. 1980).

Although the literature appears limited, relatively recent studies focused on the wide range of potential effects of aircraft noise on school children have also investigated hormonal levels between groups of children exposed to aircraft noise compared to those in a control group. Specifically, Haines, et al. (2001b and 2001c) analyzed cortisol and urinary catecholamine levels in school children as measurements of stress response to aircraft noise. In both instances, there were no differences between the aircraft-noise-exposed children and the control groups.

Other studies have reported hearing losses from exposure to aircraft noise. Noise-induced hearing loss was reportedly higher in children who attended a school located under a flight path near a Taiwan airport, as compared to children at another school far away (Chen, et al. 1997). Another study reported that hearing ability was reduced significantly in individuals who lived near an airport and were frequently exposed to aircraft noise (Chen and Chen 1993). In that study, noise exposure near the airport was reportedly uniform, with DNL greater than 75 dB and maximum noise levels of about 87 dB during overflights. Conversely, several other studies that were reviewed reported no difference in hearing ability between children exposed to high levels of airport noise and children located in quieter areas (Fisch 1977; Andrus, et al. 1975; Wu, et al. 1995).

A.3.8 Effects on Domestic Animals and Wildlife

Hearing is critical to an animal's ability to react, compete, reproduce, hunt, forage, and survive in its environment. While the existing literature does include studies on possible effects of jet aircraft noise and sonic booms on wildlife, there appears to have been little concerted effort in developing quantitative comparisons of aircraft noise effects on normal auditory characteristics. Behavioral effects have been relatively well described, but the larger ecological context issues, and the potential for drawing conclusions regarding effects on populations, has not been well developed.

The relationships between potential auditory/physiological effects and species interactions with their environments are not well understood. Manci, et al. (1988), assert that the consequences that physiological effects may have on behavioral patterns is vital to understanding the long-term effects of noise on wildlife. Questions regarding the effects (if any) on predator-prey interactions, reproductive success, and intra-inter specific behavior patterns remain.

The following discussion provides an overview of the existing literature on noise effects (particularly jet aircraft noise) on animal species. The literature reviewed here involves those studies that have focused on the observations of the behavioral effects that jet aircraft and sonic booms have on animals.

A great deal of research was conducted in the 1960's and 1970's on the effects of aircraft noise on the public and the potential for adverse ecological impacts. These studies were largely completed in response to the increase in air travel and as a result of the introduction of supersonic jet aircraft. According to Manci, et al. (1988), the foundation of information created from that focus does not necessarily correlate or provide information specific to the impacts to wildlife in areas overflown by aircraft at supersonic speed or at low altitudes.

The abilities to hear sounds and noise and to communicate assist wildlife in maintaining group cohesiveness and survivorship. Social species communicate by transmitting calls of warning, introduction, and other types that are subsequently related to an individual's or group's responsiveness.

Animal species differ greatly in their responses to noise. Noise effects on domestic animals and wildlife are classified as primary, secondary, and tertiary. Primary effects are direct, physiological changes to the auditory system, and most likely include the masking of auditory signals. Masking is defined as the inability of an individual to hear important environmental signals that may arise from mates, predators, or prey. There is some potential that noise could disrupt a species' ability to communicate or could interfere with behavioral patterns (Manci, et al. 1988). Although the effects are likely temporal, aircraft noise may cause masking of auditory signals within exposed faunal communities. Animals rely on hearing to avoid predators, obtain food, and communicate with, and attract, other members of their species. Aircraft noise may mask or interfere with these functions. Other primary effects, such as ear drum rupture or temporary and permanent hearing threshold shifts, are not as likely given the subsonic noise levels produced by aircraft overflights. Secondary effects may include non-auditory effects such as stress and hypertension; behavioral modifications; interference with mating or reproduction; and impaired ability to obtain adequate food, cover, or water. Tertiary effects are the direct result of primary and secondary effects, and include population decline and habitat loss. Most of the effects of noise are mild enough that they may never be detectable as variables of change in population size or population growth against the background of normal variation (Bowles 1995). Other environmental variables (e.g., predators, weather, changing prey base, ground-based disturbance) also influence secondary and tertiary effects, and confound the ability to identify the ultimate factor in limiting productivity of a certain nest, area, or region (Smith, et al. 1988). Overall, the literature suggests that species differ in their response to various types, durations, and sources of noise (Manci, et al. 1988).

Many scientific studies have investigated the effects of aircraft noise on wildlife, and some have focused on wildlife "flight" due to noise. Apparently, animal responses to aircraft are influenced by many variables, including size, speed, proximity (both height above the ground and lateral distance), engine noise, color, flight profile, and radiated noise. The type of aircraft (e.g., fixed wing versus rotor-wing [helicopter]) and type of flight mission may also produce different levels of disturbance, with varying animal responses (Smith, et al. 1988). Consequently, it is difficult to generalize animal responses to noise disturbances across species.

One result of the 1988 Manci, et al., literature review was the conclusion that, while behavioral observation studies were relatively limited, a general behavioral reaction in animals from exposure to aircraft noise is the startle response. The intensity and duration of the startle response appears to be dependent on which species is exposed, whether there is a group or an individual, and whether there have been some previous exposures. Responses range from flight, trampling, stampeding, jumping, or running, to movement of the head in the apparent direction of the noise source. Manci, et al. (1988), reported that the literature indicated that avian species may be more sensitive to aircraft noise than mammals.

A.3.8.1 Domestic Animals

Although some studies report that the effects of aircraft noise on domestic animals is inconclusive, a majority of the literature reviewed indicates that domestic animals exhibit some behavioral responses to military overflights but generally seem to habituate to the disturbances over a period of time. Mammals in particular appear to react to noise at sound levels higher than 90 dB, with responses including the startle response, freezing (i.e., becoming temporarily stationary), and fleeing from the sound source. Many studies on domestic animals suggest that some species appear to acclimate to some forms of sound disturbance (Manci, et al. 1988). Some studies have reported such primary and secondary effects as reduced milk production and rate of milk release, increased glucose concentrations, decreased levels of hemoglobin, increased heart rate, and a reduction in thyroid activity. These latter effects appear to represent a small percentage of the findings occurring in the existing literature.

Some reviewers have indicated that earlier studies, and claims by farmers linking adverse effects of aircraft noise on livestock, did not necessarily provide clear-cut evidence of cause and effect

(Cottereau 1978). In contrast, many studies conclude that there is no evidence that aircraft overflights affect feed intake, growth, or production rates in domestic animals.

Cattle

In response to concerns about overflight effects on pregnant cattle, milk production, and cattle safety, the U.S. Air Force prepared a handbook for environmental protection that summarizes the literature on the impacts of low-altitude flights on livestock (and poultry) and includes specific case studies conducted in numerous airspaces across the country. Adverse effects have been found in a few studies but have not been reproduced in other similar studies. One such study, conducted in 1983, suggested that 2 of 10 cows in late pregnancy aborted after showing rising estrogen and falling progesterone levels. These increased hormonal levels were reported as being linked to 59 aircraft overflights. The remaining eight cows showed no changes in their blood concentrations and calved normally (U.S. Air Force 1994b). A similar study reported abortions occurred in three out of five pregnant cattle after exposing them to flyovers by six different aircraft (U.S.Air Force 1994b). Another study suggested that feedlot cattle could stampede and injure themselves when exposed to low-level overflights (U.S. Air Force 1994b).

A majority of the studies reviewed suggests that there is little or no effect of aircraft noise on cattle. Studies presenting adverse effects to domestic animals have been limited. A number of studies (Parker and Bayley 1960; Casady and Lehmann 1967; Kovalcik and Sottnik 1971) investigated the effects of jet aircraft noise and sonic booms on the milk production of dairy cows. Through the compilation and examination of milk production data from areas exposed to jet aircraft noise and sonic boom events, it was determined that milk yields were not affected. This was particularly evident in those cows that had been previously exposed to jet aircraft noise.

A study examined the causes of 1,763 abortions in Wisconsin dairy cattle over a one-year time period and none were associated with aircraft disturbances (U.S.Air Force 1993). In 1987, Anderson contacted seven livestock operators for production data, and no effects of low-altitude and supersonic flights were noted. Three out of 43 cattle previously exposed to low-altitude flights showed a startle response to an F/A-18 aircraft flying overhead at 500 feet above ground level and 400 knots by running less than 10 meters. They resumed normal activity within one minute (U.S.Air Force 1994b). Beyer (1983) found that helicopters caused more reaction than other low-aircraft overflights, and that the helicopters at 30 to 60 feet overhead did not affect milk production and pregnancies of 44 cows and heifers in a 1964 study (U.S. Air Force 1994b).

Additionally, Beyer reported that five pregnant dairy cows in a pasture did not exhibit fright-flight tendencies or disturb their pregnancies after being overflown by 79 low-altitude helicopter flights and 4 low-altitude, subsonic jet aircraft flights (U.S. Air Force 1994b). A 1956 study found that the reactions of dairy and beef cattle to noise from low-altitude, subsonic aircraft were similar to those caused by paper blowing about, strange persons, or other moving objects (U.S. Air Force 1994b).

In a report to Congress, the U. S. Forest Service concluded that "evidence both from field studies of wild ungulates and laboratory studies of domestic stock indicate that the risks of damage are small (from aircraft approaches of 50 to 100 meters), as animals take care not to damage themselves (U.S. Forest Service 1992). If animals are overflown by aircraft at altitudes of 50 to 100 meters, there is no evidence that mothers and young are separated, that animals collide with obstructions (unless confined) or that they traverse dangerous ground at too high a rate." These varied study results suggest that, although the confining of cattle could magnify animal response to aircraft overflight, there is no proven cause-and-effect link between startling cattle from aircraft overflights and abortion rates or lower milk production.

Horses

Horses have also been observed to react to overflights of jet aircraft. Several of the studies reviewed reported a varied response of horses to low-altitude aircraft overflights. Observations made in 1966 and 1968 noted that horses galloped in response to jet flyovers (U.S. Air Force 1993). Bowles (1995) cites Kruger and Erath as observing horses exhibiting intensive flight reactions, random movements, and biting/kicking behavior. However, no injuries or abortions occurred, and there was evidence that the mares adapted somewhat to the flyovers over the course of a month (U.S. Air Force 1994b). Although horses were observed noticing the overflights, it did not appear to affect either survivability or reproductive success. There was also some indication that habituation to these types of disturbances was occurring.

LeBlanc, et al. (1991), studied the effects of F-14 jet aircraft noise on pregnant mares. They specifically focused on any changes in pregnancy success, behavior, cardiac function, hormonal production, and rate of habituation. Their findings reported observations of "flight-fright" reactions, which caused increases in heart rates and serum cortisol concentrations. The mares, however, did habituate to the noise. Levels of anxiety and mass body movements were the highest after initial exposure, with intensities of responses decreasing thereafter. There were no differences in pregnancy success when compared to a control group.

Swine

Generally, the literature findings for swine appear to be similar to those reported for cows and horses. While there are some effects from aircraft noise reported in the literature, these effects are minor. Studies of continuous noise exposure (i.e., 6 hours, 72 hours of constant exposure) reported influences on short-term hormonal production and release. Additional constant exposure studies indicated the observation of stress reactions, hypertension, and electrolyte imbalances (Dufour 1980). A study by Bond, et al. (1963), demonstrated no adverse effects on the feeding efficiency, weight gain, ear physiology, or thyroid and adrenal gland condition of pigs subjected to observed aircraft noise. Observations of heart rate increase were recorded, noting that cessation of the noise resulted in the return to normal heart rates. Conception rates and offspring survivorship did not appear to be influenced by exposure to aircraft noise.

Similarly, simulated aircraft noise at levels of 100 dB to 135 dB had only minor effects on the rate of feed utilization, weight gain, food intake, or reproduction rates of boars and sows exposed, and there were no injuries or inner ear changes observed (Manci, et al. 1988; Gladwin, et al. 1988).

Domestic Fowl

According to a 1994 position paper by the U.S. Air Force on effects of low-altitude overflights (below 1,000 ft) on domestic fowl, overflight activity has negligible effects (U.S. Air Force 1994a). The paper did recognize that given certain circumstances, adverse effects can be serious. Some of the effects can be panic reactions, reduced productivity, and effects on marketability (e.g., bruising of the meat caused during "pile-up" situations).

The typical reaction of domestic fowl after exposure to sudden, intense noise is a short-term startle response. The reaction ceases as soon as the stimulus is ended, and within a few minutes all activity returns to normal. More severe responses are possible depending on the number of birds, the frequency of exposure, and environmental conditions. Large crowds of birds, and birds not previously exposed, are more likely to pile up in response to a noise stimulus (U.S. Air Force 1994a). According to studies and interviews with growers, it is typically the previously unexposed birds that incite panic crowding, and the tendency to do so is markedly reduced within five exposures to the stimulus (U.S. Air Force 1994a). This suggests that the birds habituate relatively quickly. Egg productivity was not adversely affected by infrequent noise bursts, even at exposure levels as high as 120 to 130 dBA.

Between 1956 and 1988, there were 100 recorded claims against the Navy for alleged damage to domestic fowl. The number of claims averaged three per year, with peak numbers of claims following publications of studies on the topic in the early 1960s (U.S. Air Force 1994a). Many of the claims were disproved or did not have sufficient supporting evidence. The claims were filed for the following alleged damages: 55% for panic reactions, 31% for decreased production, 6% for reduced hatchability, 6% for weight loss, and less than 1% for reduced fertility (U.S. Air Force 1994a).

Turkeys

The review of the existing literature suggests that there has not been a concerted or widespread effort to study the effects of aircraft noise on commercial turkeys. One study involving turkeys examined the differences between simulated versus actual overflight aircraft noise, turkey responses to the noise, weight gain, and evidence of habituation (Bowles, et al. 1990a). Findings from the study suggested that turkeys habituated to jet aircraft noise quickly, that there were no growth rate differences between the experimental and control groups, and that there were some behavioral differences that increased the difficulty in handling individuals within the experimental group.

Low-altitude overflights were shown to cause turkey flocks that were kept inside turkey houses to occasionally pile up and experience high mortality rates due to the aircraft noise and a variety of disturbances unrelated to aircraft (U.S. Air Force 1994a).

A3.8.2 Wildlife

Studies on the effects of overflights and sonic booms on wildlife have been focused mostly on avian species and ungulates such as caribou and bighorn sheep. Few studies have been conducted on marine mammals, small terrestrial mammals, reptiles, amphibians, and carnivorous mammals. Generally, species that live entirely below the surface of the water have also been ignored due to the fact they do not experience the same level of sound as terrestrial species (National Park Service 1994). Wild ungulates appear to be much more sensitive to noise disturbance than domestic livestock (Manci, et al. 1988). This may be due to previous exposure to disturbances. One common factor appears to be that low-altitude flyovers seem to be more disruptive in terrain where there is little cover (Manci, et al. 1988).

A.3.8.2.1 MAMMALS

Terrestrial Mammals

Studies of terrestrial mammals have shown that noise levels of 120 dBA can damage mammals' ears, and levels at 95 dBA can cause temporary loss of hearing acuity. Noise from aircraft has affected other large carnivores by causing changes in home ranges, foraging patterns, and breeding behavior. One study recommended that aircraft not be allowed to fly at altitudes below 2,000 feet above ground level over important grizzly and polar bear habitat (Dufour 1980). Wolves have been frightened by low-altitude flights that were 25 to 1,000 feet off the ground. However, wolves have been found to adapt to aircraft overflights and noise as long as they were not being hunted from aircraft (Dufour 1980).

Wild ungulates (American bison, caribou, bighorn sheep) appear to be much more sensitive to noise disturbance than domestic livestock (Weisenberger, et al. 1996). Behavioral reactions may be related to the past history of disturbances by such things as humans and aircraft. Common reactions of reindeer kept in an enclosure exposed to aircraft noise disturbance were a slight startle response, raising of the head, pricking ears, and scenting of the air. Panic reactions and extensive changes in behavior of individual animals were not observed. Observations of caribou in Alaska exposed to fixed-wing aircraft and helicopters showed running and panic reactions occurred when overflights were at an altitude of 200 feet or less. The reactions decreased with increased altitude of overflights, and, with more than 500 feet in altitude, the panic reactions stopped. Also, smaller groups reacted less strongly than larger groups. One negative effect of the running and avoidance behavior is increased expenditure of energy. For a 90-kg animal, the calculated expenditure due to aircraft harassment is 64 kilocalories per minute when running and 20 kilocalories per minute when walking. When conditions are favorable, this expenditure can be counteracted with increased feeding; however, during harsh winter conditions, this may not be possible. Incidental observations of wolves and bears exposed to fixed-wing aircraft and helicopters in the northern regions suggested that wolves are less disturbed than wild ungulates, while grizzly bears showed the greatest response of any animal species observed.

It has been proven that low-altitude overflights do induce stress in animals. Increased heart rates, an indicator of excitement or stress, have been found in pronghorn antelope, elk, and bighorn sheep. As such reactions occur naturally as a response to predation, infrequent overflights may not, in and of themselves, be detrimental. However, flights at high frequencies over a long period of time may cause harmful effects. The consequences of this disturbance, while cumulative, is not additive. It may be that aircraft disturbance may not cause obvious and serious health effects, but coupled with a harsh winter, it may have an adverse impact. Research has shown that stress induced by other types of disturbances produces long-term decreases in metabolism and hormone balances in wild ungulates.

Behavioral responses can range from mild to severe. Mild responses include head raising, body shifting, or turning to orient toward the aircraft. Moderate disturbance may be nervous behaviors, such as trotting a short distance. Escape is the typical severe response.

Marine Mammals

The physiological composition of the ear in aquatic and marine mammals exhibits adaptation to the aqueous environment. These differences (relative to terrestrial species) manifest themselves in the auricle and middle ear (Manci, et al. 1988). Some mammals use echolocation to perceive objects in their surroundings and to determine the directions and locations of sound sources (Simmons 1983 in Manci, et al. 1988).

In 1980, the Acoustical Society of America held a workshop to assess the potential hazard of manmade noise associated with proposed Alaska Arctic (North Slope-Outer Continental Shelf) petroleum operations on marine wildlife and to prepare a research plan to secure the knowledge necessary for proper assessment of noise impacts (Acoustical Society of America, 1980). Since 1980 it appears that research on responses of aquatic mammals to aircraft noise and sonic booms has been limited. Research conducted on northern fur seals, sea lions, and ringed seals indicated that there are some differences in how various animal groups receive frequencies of sound. It was observed that these species exhibited varying intensities of a startle response to airborne noise, which was habituated over time. The rates of habituation appeared to vary with species, populations, and demographics (age, sex). Time of day of exposure was also a factor (Muyberg 1978 in Manci, et al. 1988).

Studies accomplished near the Channel Islands were conducted near the area where the space shuttle launches occur. It was found that there were some response differences between species relative to the loudness of sonic booms. Those booms that were between 80 and 89 dBA caused a greater intensity of startle reactions than lower-intensity booms at 72 to 79 dBA. However, the duration of the startle responses to louder sonic booms was shorter (Jehl and Cooper 1980 in Manci, et al. 1988).

Jehl and Cooper (1980) indicated that low-flying helicopters, loud boat noises, and humans were the most disturbing to pinnipeds. According to the research, while the space launch and associated operational activity noises have not had a measurable effect on the pinniped population, it also suggests that there was a greater "disturbance level" exhibited during launch activities. There was a recommendation to continue observations for behavioral effects and to perform long-term population monitoring (Jehl and Cooper 1980).

The continued presence of single or multiple noise sources could cause marine mammals to leave a preferred habitat. However, it does not appear likely that overflights could cause migration from suitable habitats as aircraft noise over water is mobile and would not persist over any particular area. Aircraft noise, including supersonic noise, currently occurs in the overwater airspace of Eglin, Tyndall, and Langley AFBs from sorties predominantly involving jet aircraft. Survey results reported in Davis, et al. (2000), indicate that cetaceans (i.e., dolphins) occur under all of the Eglin and Tyndall marine airspace. The continuing presence of dolphins indicates that aircraft noise does not discourage use of the area and apparently does not harm the locally occurring population.

In a summary by the National Parks Service (1994) on the effects of noise on marine mammals, it was determined that gray whales and harbor porpoises showed no outward behavioral response to aircraft noise or overflights. Bottlenose dolphins showed no obvious reaction in a study involving helicopter overflights at 1,200 to 1,800 feet above the water. Neither did they show any reaction to survey aircraft unless the shadow of the aircraft passed over them, at which point there was some observed tendency to dive (Richardson, et al. 1995). Other anthropogenic noises in the marine environment from ships and pleasure craft may have more of an effect on marine mammals than aircraft noise (U.S. Air Force 2000). The noise effects on cetaceans appear to be somewhat attenuated by the air/water interface. The cetacean fauna along the coast of California have been subjected to sonic booms from military aircraft for many years without apparent adverse effects (Tetra Tech, Inc. 1997).

Manatees appear relatively unresponsive to human-generated noise to the point that they are often suspected of being deaf to oncoming boats [although their hearing is actually similar to that of pinnipeds (Bullock, et al. 1980)]. Little is known about the importance of acoustic communication to manatees, although they are known to produce at least ten different types of sounds and are thought to have sensitive hearing (Richardson, et al. 1995). Manatees continue to occupy canals near Miami International Airport, which suggests that they have become habituated to human disturbance and noise (Metro-Dade County 1995). Since manatees spend most of their time below the surface and do not startle readily, no effect of aircraft overflights on manatees would be expected (Bowles, et al. 1991b).

A.3.8.2.2 BIRDS

Auditory research conducted on birds indicates that they fall between the reptiles and the mammals relative to hearing sensitivity. According to Dooling (1978), within the range of 1 to 5 kHz, birds show a level of hearing sensitivity similar to that of the more sensitive mammals. In contrast to mammals, bird sensitivity falls off at a greater rate to increasing and decreasing frequencies. Passive observations and studies examining aircraft bird strikes indicate that birds nest and forage near airports. Aircraft noise in the vicinity of commercial airports apparently does not inhibit bird presence and use.

High-noise events (like a low-altitude aircraft overflight) may cause birds to engage in escape or avoidance behaviors, such as flushing from perches or nests (Ellis, et al. 1991). These activities impose an energy cost on the birds that, over the long term, may affect survival or growth. In addition, the birds may spend less time engaged in necessary activities like feeding, preening, or caring for their young because they spend time in noise-avoidance activity. However, the long-term significance of noise-related impacts is less clear. Several studies on nesting raptors have indicated that birds become habituated to aircraft overflights and that long-term reproductive success is not affected (Grubb and King 1991; Ellis, et al. 1991). Threshold noise levels for significant responses range from 62 dB for Pacific black brant (Branta bernicla nigricans) (Ward and Stehn 1990) to 85 dB for crested tern (Sterna bergii) (Brown 1990).

Songbirds were observed to become silent prior to the onset of a sonic boom event (F-111 jets), followed by "raucous discordant cries." There was a return to normal singing within 10 seconds after the boom (Higgins 1974 in Manci, et al. 1988). Ravens responded by emitting protestation calls, flapping their wings, and soaring.

Manci, et al. (1988), reported a reduction in reproductive success in some small territorial passerines (i.e., perching birds or songbirds) after exposure to low-altitude overflights. However, it has been observed that passerines are not driven any great distance from a favored food source by a nonspecific disturbance, such as aircraft overflights (U.S. Forest Service 1992). Further study may be warranted.

A recent study, conducted cooperatively between the DoD and the USFWS, assessed the response of the red-cockaded woodpecker to a range of military training noise events, including artillery, small arms, helicopter, and maneuver noise (Pater, et al. 1999). The project findings show that the red-cockaded woodpecker successfully acclimates to military noise events. Depending on the noise level that ranged from innocuous to very loud, the birds responded by flushing from their nest cavities. When the noise source was closer and the noise level was higher, the number of flushes increased proportionately. In all cases, however, the birds returned to their nests within a relatively short period of time (usually within 12 minutes). Additionally, the noise exposure did not result in any mortality or statistically detectable changes in reproductive success (Pater, et al. 1999). Red-cockaded woodpeckers did not flush when artillery simulators were more than 122 meters away and SEL noise levels were 70 dBA.

Lynch and Speake (1978) studied the effects of both real and simulated sonic booms on the nesting and brooding eastern wild turkey (Meleagris gallopavo silvestris) in Alabama. Hens at four nest sites were subjected to between 8 and 11 combined real and simulated sonic booms. All tests elicited similar responses, including quick lifting of the head and apparent alertness for between 10 and 20 seconds. No apparent nest failure occurred as a result of the sonic booms.

Twenty-one brood groups were also subjected to simulated sonic booms. Reactions varied slightly between groups, but the largest percentage of groups reacted by standing motionless after the initial blast. Upon the sound of the boom, the hens and poults fled until reaching the edge of the woods (approximately 4 to 8 meters). Afterward, the poults resumed feeding activities while the hens remained alert for a short period of time (approximately 15 to 20 seconds). In no instances were poults abandoned, nor did they scatter and become lost. Every observation group returned to normal activities within a maximum of 30 seconds after a blast.

A3.8.2.2.1 RAPTORS

In a literature review of raptor responses to aircraft noise, Manci, et al. (1988), found that most raptors did not show a negative response to overflights. When negative responses were observed they were predominantly associated with rotor-winged aircraft or jet aircraft that were repeatedly passing within 0.5 mile of a nest.

Ellis, et al. (1991), performed a study to estimate the effects of low-level military jet aircraft and mid- to high-altitude sonic booms (both actual and simulated) on nesting peregrine falcons and seven other raptors (common black-hawk, Harris' hawk, zone-tailed hawk, red-tailed hawk, golden eagle, prairie falcon, bald eagle). They observed responses to test stimuli, determined nest success for the year of the testing, and evaluated site occupancy the following year. Both long- and short-term effects were noted in the study. The results reported the successful fledging of young in 34 of 38 nest sites (all eight species) subjected to low-level flight and/or simulated sonic booms. Twenty-two of the test sites were revisited in the following year, and observations of pairs or lone birds were made at all but one nest. Nesting attempts were underway at 19 of 20 sites that were observed long enough to be certain of breeding activity. Reoccupancy and productivity rates were within or above expected values for self-sustaining populations.

Short-term behavior responses were also noted. Overflights at a distance of 150 m or less produced few significant responses and no severe responses. Typical responses consisted of crouching or, very rarely, flushing from the perch site. Significant responses were most evident before egg laying and after young were "well grown." Incubating or brooding adults never burst from the nest, thus preventing egg breaking or knocking chicks out of the nest. Jet passes and sonic booms often caused noticeable alarm; however, significant negative responses were rare and did not appear to limit productivity or reoccupancy. Due to the locations of some of the nests, some birds may have been habituated to aircraft noise. There were some test sites located at distances far from zones of frequent military aircraft usage, and the test stimuli were often closer, louder, and more frequent than would be likely for a normal training situation.

Manci, et al. (1988), noted that a female northern harrier was observed hunting on a bombing range in Mississippi during bombing exercises. The harrier was apparently unfazed by the exercises, even when a bomb exploded within 200 feet. In a similar case of habituation/non-disturbance, a study on the Florida snail-kite stated the greatest reaction to overflights (approximately 98 dBA) was "watching the aircraft fly by." No detrimental impacts to distribution, breeding success, or behavior were noted.

Bald Eagle

A study by Grubb and King (1991) on the reactions of the bald eagle to human disturbances showed that terrestrial disturbances elicited the greatest response, followed by aquatic (i.e., boats) and aerial disturbances. The disturbance regime of the area where the study occurred was predominantly characterized by aircraft noise. The study found that pedestrians consistently caused responses that were greater in both frequency and duration. Helicopters elicited the highest level of aircraft-related responses. Aircraft disturbances, although the most common form of disturbance, resulted in the lowest levels of response. This low response level may have been due to habituation; however, flights less than 170 meters away caused reactions similar to other disturbance types. Ellis, et al. (1991), showed that eagles typically respond to the proximity of a disturbance, such as a pedestrian or aircraft within 100 meters, rather than the noise level. Fleischner and Weisberg (1986) stated that reactions of bald eagles to commercial jet flights, although minor (e.g., looking), were twice as likely to occur when the jets passed at a distance of 0.5 mile or less. They also noted that helicopters were four times more likely to cause a reaction than a commercial jet and 20 times more likely to cause a reaction than a propeller plane.

The USFWS advised Cannon AFB that flights at or below 2,000 feet AGL from October 1 through March 1 could result in adverse impacts to wintering bald eagles (U.S. Fish and Wildlife Serice 1998). However, Fraser, et al. (1985), suggested that raptors habituate to overflights rapidly, sometimes tolerating aircraft approaches of 65 feet or less.

Osprey

A study by Trimper, et al. (1998), in Goose Bay, Labrador, Canada, focused on the reactions of nesting osprey to military overflights by CF-18 Hornets. Reactions varied from increased alertness and focused observation of planes to adjustments in incubation posture. No overt reactions (e.g., startle response, rapid nest departure) were observed as a result of an overflight. Young nestlings crouched as a result of any disturbance until they grew to 1 to 2 weeks prior to fledging. Helicopters, human presence, float planes, and other ospreys elicited the strongest reactions from nesting ospreys. These responses included flushing, agitation, and aggressive displays. Adult osprey showed high nest occupancy rates during incubation regardless of external influences.

The osprey observed occasionally stared in the direction of the flight before it was audible to the observers. The birds may have been habituated to the noise of the flights; however, overflights were strictly controlled during the experimental period. Strong reactions to float planes and helicopter may have been due to the slower flight and therefore longer duration of visual stimuli rather than noise-related stimuli.

Red-tailed Hawk

Anderson, et al. (1989), conducted a study that investigated the effects of low-level helicopter overflights on 35 red-tailed hawk nests. Some of the nests had not been flown over prior to the study.

The hawks that were naïve (i.e., not previously exposed) to helicopter flights exhibited stronger avoidance behavior (nine of 17 birds flushed from their nests) than those that had experienced prior overflights. The overflights did not appear to affect nesting success in either study group. These findings were consistent with the belief that red-tailed hawks habituate to low-level air traffic, even during the nesting period.

A.3.8.2.2.2 MIGRATORY WATERFOWL

A study of caged American black ducks was conducted by Fleming, et al. in 1996. It was determined that noise had negligible energetic and physiologic effects on adult waterfowl. Measurements included body weight, behavior, heart rate, and enzymatic activity. Experiments also showed that adult ducks exposed to high noise events acclimated rapidly and showed no effects.

The study also investigated the reproductive success of captive ducks, which indicated that duckling growth and survival rates at Piney Island, North Carolina, were lower than those at a background location. In contrast, observations of several other reproductive indices (i.e., pair formation, nesting, egg production, and hatching success) showed no difference between Piney Island and the background location. Potential effects on wild duck populations may vary, as wild ducks at Piney Island have presumably acclimated to aircraft overflights. It was not demonstrated that noise was the cause of adverse impacts. A variety of other factors, such as weather conditions, drinking water and food availability and variability, disease, and natural variability in reproduction, could explain the observed effects. Fleming noted that drinking water conditions (particularly at Piney Island) deteriorated during the study, which could have affected the growth of young ducks. Further research would be necessary to determine the cause of any reproductive effects.

Another study by Conomy, et al. (1998) exposed previously unexposed ducks to 71 noise events per day that equaled or exceeded 80 dBA. It was determined that the proportion of time black ducks reacted to aircraft activity and noise decreased from 38 percent to 6 percent in 17 days and remained stable at 5.8 percent thereafter. In the same study, the wood duck did not appear to habituate to aircraft disturbance. This supports the notion that animal response to aircraft noise is species-specific. Because a startle response to aircraft noise can result in flushing from nests, migrants and animals living in areas with high concentrations of predators would be the most vulnerable to experiencing effects of lowered birth rates and recruitment over time. Species that are subjected to infrequent overflights do not appear to habituate to overflight disturbance as readily.

Black brant studied in the Alaska Peninsula were exposed to jets and propeller aircraft, helicopters, gunshots, people, boats, and various raptors. Jets accounted for 65% of all the disturbances. Humans, eagles, and boats caused a greater percentage of brant to take flight. There was markedly greater reaction to Bell-206-B helicopter flights than fixed wing, single-engine aircraft (Ward, et al. 1986).

The presence of humans and low-flying helicopters in the Mackenzie Valley North Slope area did not appear to affect the population density of Lapland longspurs, but the experimental group was shown to have reduced hatching and fledging success and higher nest abandonment. Human presence appeared to have a greater impact on the incubating behavior of the black brant, common eider, and Arctic tern than fixed-wing aircraft (Gunn and Livingston 1974).

Gunn and Livingston (1974) found that waterfowl and seabirds in the Mackenzie Valley and North Slope of Alaska and Canada became acclimated to float plane disturbance over the course of three days. Additionally, it was observed that potential predators (bald eagle) caused a number of birds to leave their nests. Non-breeding birds were observed to be more reactive than breeding birds. Waterfowl were affected by helicopter flights, while snow geese were disturbed by Cessna 185 flights. The geese flushed when the planes were under 1,000 feet, compared to higher flight elevations. An overall reduction in flock sizes was observed. It was recommended that aircraft flights be reduced in the vicinity of premigratory staging areas.

Manci, et al. 1988 reported that waterfowl were particularly disturbed by aircraft noise. The most sensitive appeared to be snow geese. Canada geese and snow geese were thought to be more sensitive than other animals such as turkey vultures, coyotes, and raptors (Edwards, et al. 1979).

A.3.8.2.2.3 WADING AND SHORE BIRDS

Black, et al. (1984), studied the effects of low-altitude (less than 500 feet AGL) military training flights with sound levels from 55 to 100 dBA on wading bird colonies (i.e., great egret, snowy egret, tricolored heron, and little blue heron). The training flights involved three or four aircraft, which occurred once or twice per day. This study concluded that the reproductive activity--including nest success, nestling survival, and nestling chronology--was independent of F-16 overflights. Dependent variables were more strongly related to ecological factors, including location and physical characteristics of the colony and climatology. Another study on the effects of circling fixed-wing aircraft and helicopter overflights on wading bird colonies found that at altitudes of 195 to 390 feet, there was no reaction in nearly 75% of the 220 observations. Ninety percent displayed no reaction or merely looked toward the direction of the noise source. Another 6 percent stood up, 3 percent walked from the nest, and 2 percent flushed (but were without active nests) and returned within 5 minutes (Kushlan 1978). Apparently, non-nesting wading birds had a slightly higher incidence of reacting to overflights than nesting birds. Seagulls observed roosting near a colony of wading birds in another study remained at their roosts when subsonic aircraft flew overhead (Burger 1981). Colony distribution appeared to be most directly correlated to available wetland community types and was found to be distributed randomly with respect to military training routes. These results suggest that wading bird species presence was most closely linked to habitat availability and that they were not affected by low-level military overflights (U.S. Air Force 2000).

Burger (1986) studied the response of migrating shorebirds to human disturbance and found that shorebirds did not fly in response to aircraft overflights, but did flush in response to more localized intrusions (i.e., humans and dogs on the beach). Burger (1981) studied the effects of noise from JFK Airport in New York on herring gulls that nested less than 1 kilometer from the airport. Noise levels over the nesting colony were 85 to 100 dBA on approach and 94 to 105 dBA on takeoff. Generally, there did not appear to be any prominent adverse effects of subsonic aircraft on nesting, although some birds flushed when the concorde flew overhead and, when they returned, engaged in aggressive behavior. Groups of gulls tended to loaf in the area of the nesting colony, and these birds remained at the roost when the concorde flew overhead. Up to 208 of the loafing gulls flew when supersonic aircraft flew overhead. These birds would circle around and immediately land in the loafing flock (U.S. Air Force 2000).

In 1970, sonic booms were potentially linked to a mass hatch failure of Sooty Terns on the Dry Tortugas (Austin, et al. 1970). The cause of the failure was not certain, but it was conjectured that sonic booms from military aircraft or an overgrowth of vegetation were factors. In the previous season, Sooties were observed to react to sonic booms by rising in a "panic flight," circling over the island, then usually settling down on their eggs again. Hatching that year was normal. Following the

1969 hatch failure, excess vegetation was cleared and measures were taken to reduce supersonic activity. The 1970 hatch appeared to proceed normally. A colony of Noddies on the same island hatched successfully in 1969, the year of the Sooty hatch failure.

Subsequent laboratory tests of exposure of eggs to sonic booms and other impulsive noises (Bowles, et al. 1991a; Bowles, et al. 1994; Cottereau 1972; Cogger and Zegarra 1980) failed to show adverse effects on hatching of eggs. A structural analysis (Ting, et al. 2002) showed that, even under extraordinary circumstances, sonic booms would not damage an avian egg.

Burger (1981) observed no effects of subsonic aircraft on herring gulls in the vicinity of JFK International Airport. The concorde aircraft did cause more nesting gulls to leave their nests (especially in areas of higher density of nests), causing the breakage of eggs and the scavenging of eggs by intruder prey. Clutch sizes were observed to be smaller in areas of higher-density nesting (presumably due to the greater tendency for panic flight) than in areas where there were fewer nests.

A3.8.3 Fish, Reptiles, and Amphibians

The effects of overflight noise on fish, reptiles, and amphibians have been poorly studied, but conclusions regarding their expected responses have involved speculation based upon known physiologies and behavioral traits of these taxa (Gladwin, et al. 1988). Although fish do startle in response to low-flying aircraft noise, and probably to the shadows of aircraft, they have been found to habituate to the sound and overflights. Reptiles and amphibians that respond to low frequencies and those that respond to ground vibration, such as spadefoots (genus Scaphiopus), may be affected by noise. Limited information is available on the effects of short-duration noise events on reptiles. Dufour (1980) and Manci, et al. (1988), summarized a few studies of reptile responses to noise. Some reptile species tested under laboratory conditions experienced at least temporary threshold shifts or hearing loss after exposure to 95 dB for several minutes. Crocodilians in general have the most highly developed hearing of all reptiles. Crocodile ears have lids that can be closed when the animal goes under water. These lids can reduce the noise intensity by 10 to 12 dB (Wever and Vernon 1957). On Homestead Air Reserve Station, Florida, two crocodilians (the American Alligator and the Spectacled Caiman) reside in wetlands and canals along the base runway suggesting that they can coexist with existing noise levels of an active runway including DNLs of 85 dB.

A3.8.4 Summary

Some physiological/behavioral responses such as increased hormonal production, increased heart rate, and reduction in milk production have been described in a small percentage of studies. A majority of the studies focusing on these types of effects have reported short-term or no effects.

The relationships between physiological effects and how species interact with their environments have not been thoroughly studied. Therefore, the larger ecological context issues regarding physiological effects of jet aircraft noise (if any) and resulting behavioral pattern changes are not well understood.

Animal species exhibit a wide variety of responses to noise. It is therefore difficult to generalize animal responses to noise disturbances or to draw inferences across species, as reactions to jet aircraft noise appear to be species-specific. Consequently, some animal species may be more sensitive than other species and/or may exhibit different forms or intensities of behavioral responses. For instance, wood ducks appear to be more sensitive and more resistant to acclimation to jet aircraft noise than

Canada geese in one study. Similarly, wild ungulates seem to be more easily disturbed than domestic animals.

The literature does suggest that common responses include the "startle" or "fright" response and, ultimately, habituation. It has been reported that the intensities and durations of the startle response decrease with the numbers and frequencies of exposures, suggesting no long-term adverse effects. The majority of the literature suggests that domestic animal species (cows, horses, chickens) and wildlife species exhibit adaptation, acclimation, and habituation after repeated exposure to jet aircraft noise and sonic booms.

Animal responses to aircraft noise appear to be somewhat dependent on, or influenced by, the size, shape, speed, proximity (vertical and horizontal), engine noise, color, and flight profile of planes. Helicopters also appear to induce greater intensities and durations of disturbance behavior as compared to fixed-wing aircraft. Some studies showed that animals that had been previously exposed to jet aircraft noise exhibited greater degrees of alarm and disturbance to other objects creating noise, such as boats, people, and objects blowing across the landscape. Other factors influencing response to jet aircraft noise may include wind direction, speed, and local air turbulence; landscape structures (i.e., amount and type of vegetative cover); and, in the case of bird species, whether the animals are in the incubation/nesting phase.

A.3.9 Property Values

Property within a noise zone (or Accident Potential Zone) may be affected by the availability of federally guaranteed loans. According to U.S. Department of Housing and Urban Development (HUD), Federal Housing Administration (FHA), and Veterans Administration (VA) guidance, sites are acceptable for program assistance, subsidy, or insurance for housing in noise zones of less than 65 DNL, and sites are conditionally acceptable with special approvals and noise attenuation in the 65 to 75 DNL noise zone and the greater than 75 DNL noise zone. HUD's position is that noise is not the only determining factor for site acceptability, and properties should not be rejected only because of airport influences if there is evidence of acceptability within the market and if use of the dwelling is expected to continue. Similar to the Navy's and Air Force's Air Installation Compatible Use Zone Program, HUD, FHA, and VA recommend sound attenuation for housing in the higher noise zones and written disclosures to all prospective buyers or lessees of property within a noise zone (or Accident Potential Zone).

Newman and Beattie (1985) reviewed the literature to assess the effect of aircraft noise on property values. One paper by Nelson (1978), reviewed by Newman and Beattie, suggested a 1.8 to 2.3 percent decrease in property value per decibel at three separate airports, while at another period of time, they found only a 0.8 percent devaluation per decibel change in DNL. However, Nelson also noted a decline in noise depreciation over time which he theorized could be due to either noise sensitive people being replaced by less sensitive people or the increase in commerical value of the property near airports; both ideas were supported by Crowley (1978). Ultimately, Newman and Beattie summarized that while an effect of noise was observed, noise is only one of the many factors that is part of a decision to move close to, or away from, an airport, but which is sometimes considered an advantage due to increased opportunities for employment or ready access to the airport itself. With all the issues associated with determining property values, their reviews found that decreases in property values usually range from 0.5 to 2 percent per decibel increase of cumulative noise exposure.

More recently Fidell, et al. (1996) studied the influences of aircraft noise on actual sale prices of residential properties in the vicinity of two military facilities and found that equations developed for one area to predict residential sale prices in areas unaffected by aircraft noise worked equally well when applied to predicting sale prices of homes in areas with aircraft noise in excess of LDN 65dB. Thus, the model worked equally well in predicting sale prices in areas with and without aircraft noise exposure. This indicates that aircraft noise had no meaningful effect on residential property values. In some cases, the average sale prices of noise exposed properties were somewhat higher than those elsewhere in the same area. In the vicinity of Davis-Monthan AFB/Tucson, AZ, Fidell found the homes near the airbase were much older, smaller and in poorer condition than homes elsewhere. These factors caused the equations developed for predicting sale prices in areas further away from the base to be inapplicable with those nearer the base. However, again Fidell found that, similar to other researchers, differences in sale prices between homes with and without aircraft noise were frequently due to factors other than noise itself.

A.3.10 Noise Effects on Structures

Normally, the most sensitive components of a structure to airborne noise are the windows and, infrequently, the plastered walls and ceilings. An evaluation of the peak sound pressures impinging on the structure is normally used to determine the possibility of damage. In general, with peak sound levels above 130 dB, there is the possibility of the excitation of structural component resonances. While certain frequencies (such as 30 hertz for window breakage) may be of more concern than other frequencies, conservatively, only sounds lasting more than one second above a sound level of 130 dB are potentially damaging to structural components (Committee on Hearing, Bioacoustics, and Biomechanics 1977).

Noise-induced structural vibration may also cause annoyance to dwelling occupants because of induced secondary vibrations, or rattling of objects within the dwelling such as hanging pictures, dishes, plaques, and bric-a-brac. Window panes may also vibrate noticeably when exposed to high levels of airborne noise. In general, such noise-induced vibrations occur at peak sound levels of 110 dB or greater. Thus, assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

A.3.11 Noise Effects on Terrain

It has been suggested that noise levels associated with low-flying aircraft may affect the terrain under the flight path by disturbing fragile soil or snow, especially in mountainous areas, causing landslides or avalanches. There are no known instances of such effects, and it is considered improbable that such effects would result from routine, subsonic aircraft operations.

A.3.12 Noise Effects on Historical and Archaeological Sites

Because of the potential for increased fragility of structural components of historical buildings and other historical sites, aircraft noise may affect such sites more severely than newer, modern structures. Particularly in older structures, seemingly insignificant surface cracks initiated by vibrations from aircraft noise may lead to greater damage from natural forces (Hanson, et al. 1991). There are few scientific studies of such effects to provide guidance for their assessment.

One study involved the measurements of sound levels and structural vibration levels in a superbly restored plantation house, originally built in 1795, and now situated approximately 1,500 feet from the centerline at the departure end of Runway 19L at Washington Dulles International Airport. These measurements were made in connection with the proposed scheduled operation of the supersonic Concorde airplane at Dulles (Wesler 1977). There was special concern for the building's windows, since roughly half of the 324 panes were original. No instances of structural damage were found. Interestingly, despite the high levels of noise during Concorde takeoffs, the induced structural vibration levels were actually less than those induced by touring groups and vacuum cleaning.

As noted above for the noise effects of noise-induced vibrations of conventional structures, assessments of noise exposure levels for normally compatible land uses should also be protective of historic and archaeological sites.

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