Redwood City General Plan Noise and Vibration Background Report

Setting

Noise Fundamentals

Sound is caused by a vibrating surface that causes the air pressure to fluctuate sympathetically. A sound is usually considered objectionable because it is disturbing or annoying. The objectionable nature of sound could be caused by its pitch or its loudness. Loudness is intensity of sound waves combined with the reception characteristics of the ear. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave. Higher pitched signals sound louder to humans than sounds with a lower pitch.

To account for the concepts of pitch and loudness, there are several noise measurement scales that are used to describe noise in a particular location. A decibel (dB) is a unit of measurement that indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc. There is a relationship between the subjective noisiness or loudness of a sound and its intensity. Each 10-decibel increase in sound level is perceived as approximately a doubling of loudness over a fairly wide range of intensities. Technical terms are defined in Table 1.

TABLE 1 Definitions of Acoustical Terms Used in this Report	
Term	**Definitions**
Decibel, dB	A unit describing the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro Pascals (micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e.g., 20 micro Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sound are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, L_{eq}	The average A-weighted noise level during the measurement period. The hourly Leq used for this report is denoted as dBA Leq[h].
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 pm to 10:00 pm and after addition of 10 decibels to sound levels in the night between 10:00 pm and 7:00 am.
Day/Night Noise Level, L_{dn}	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 pm and 7:00 am.
L_{01}, L_{10}, L_{50}, L_{90}	The A-weighted noise levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

The level of noise depends upon the distance from the source to the receiver. If a noise source is at a single point (e.g., a swimming pool pump), the noise level is reduced 6 dB with each doubling of the distance. Along a roadway, where the noise results from a line of traffic, the level drops 3 dB with each doubling of the distance from the road.

There are several methods of characterizing sound. The most common in California is the A-weighted sound level abbreviated dBA. This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table 2. Since sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This energy-equivalent descriptor is called L_{eq}. The most common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration.

The scientific instrument used to measure noise is the sound level meter. Sound level meters can accurately measure environmental noise levels to within about plus or minus 1 dBA. Various computer models are used to predict environmental noise levels from sources such as roadways and airports. The accuracy of the predictive models depends upon the distance the receptor is from the noise source. Close to the noise source, the models are accurate to within about plus or minus 1 to 2 dBA.

Since the sensitivity to noise increases during the evening and at night -- because excessive noise interferes with the ability to sleep -- 24-hour descriptors have been developed that incorporate artificial noise penalties added to quiet-time noise events. The Community Noise Equivalent Level, CNEL, is a measure of the cumulative noise exposure in a community, with a 5 dB penalty added to evening (7:00 PM - 10:00 PM) and a 10 dB penalty added to nocturnal (10:00 PM - 7:00 AM) noise levels. The Day/Night Average Sound Level, L_{dn}, is essentially the same as CNEL, with the exception that the evening penalty is dropped and all occurrences during this three-hour period are grouped into the daytime period. The state guidelines require that the Noise Element utilize L_{dn} or CNEL to describe the noise environment and its effects.

TABLE 2 Typical Noise Levels in the Environment		
Common Outdoor Noise Source	**Noise Level (dBA)**	**Common Indoor Noise Source**
	120 dBA	
Jet fly-over at 300 meters		Rock concert
	110 dBA	
Pile driver at 20 meters	100 dBA	
		Night club with live music
	90 dBA	
Large truck pass by at 15 meters		
	80 dBA	Noisy restaurant
		Garbage disposal at 1 meter
Gas lawn mower at 30 meters	70 dBA	Vacuum cleaner at 3 meters
Commercial/Urban area daytime		Normal speech at 1 meter
Suburban expressway at 90 meters	60 dBA	
Suburban daytime		Active office environment
	50 dBA	
Urban area nighttime		Quiet office environment
	40 dBA	
Suburban nighttime Quiet rural areas	30 dBA	Library
		Quiet bedroom at night
Wilderness area	20 dBA	
	10 dBA	Quiet recording studio
Threshold of human hearing	0 dBA	Threshold of human hearing

Groundborne Vibration Fundamentals

Railroad trains are potential sources of substantial ground vibration depending on distance, the type and the speed of trains, and the type of railroad track. People's response to ground vibration has been correlated best with the velocity of the ground. The velocity of the ground is expressed on the decibel scale. The reference velocity is 1×10^{-6} in./sec. RMS, which equals 0 VdB, and 1 in./sec. equals 120 VdB. Although not a universally accepted notation, the abbreviation "VdB" is used in this document for vibration decibels to reduce the potential for confusion with sound decibels.

Typical background vibration levels in residential areas are usually 50 VdB or lower, well below the threshold of perception for most humans. Perceptible vibration levels inside residences are attributed to the operation of heating and air conditioning systems, door slams, and foot traffic. Construction activities, train operations, and street traffic are some of the most common external sources of vibration that can be perceptible inside residences. Table 3 illustrates some common sources of vibration and the association to human perception or the potential for structural damage.

TABLE 3 Typical Levels of Groundborne Vibration

Human/Structural Response	Velocity Level, VdB (re 1µinch/sec, RMS)	Typical Events (50 –foot setback)
Threshold, minor cosmetic damage	100	Blasting, pile driving, vibratory compaction equipment
		Heavy tracked vehicles (Bulldozers, cranes, drill rigs)
Difficulty with tasks such as reading a video or computer screen	90	
		Commuter rail, upper range
Residential annoyance, infrequent events	80	Rapid transit, upper range
Residential annoyance, occasional events		Commuter rail, typical Bus or truck over bump or on rough roads
Residential annoyance, frequent events	70	Rapid transit, typical
Approximate human threshold of perception to vibration		Buses, trucks and heavy street traffic
	60	
		Background vibration in residential settings in the absence of activity
Lower limit for equipment ultra-sensitive to vibration	50	

Summary

Regulatory Framework

Redwood City General Plan

Redwood City addresses issues of land use compatibility, transportation noise, and community noise in the *Noise Element* of the City of Redwood City Strategic General Plan (adopted in 1990). The 1990 Noise Element set forth three noise objectives and seven policies. These are broad statements of major noise goals for the City, which are implemented through various means, including the City's Noise Ordinance, described below. The City's Noise Guidelines for Land Use Compatibility are presented in Table 4. The New General Plan offers the opportunity to replace, revise, and/or bolster the objectives and policies and to consider new implementation measures to help insure that the intent of the goals and policies can be achieved.

Noise Objectives from 1990 General Plan

1. Minimize the impact of noise on people through noise reduction and suppression techniques, and through appropriate land use policies.
2. Reduce future impact of all types of point source noises.
3. Reduce ambient noise levels in all parts of the City to safe, optimum levels.

Noise Policies from 1990 General Plan

N-1: Include appropriate noise attenuation techniques in the design of all new arterial streets.

N-2: Limit the hours of operation at all noise generation sources wherever practicable, unless an emergency exists.

N-3: Require all exterior noise sources (construction, operations, air compressors, pumps, fans, and leaf blowers) to use available noise suppression devices and techniques to bring exterior noise down to acceptable levels compatible with adjacent land uses.

N-5: Require that Land Uses within the Planning Boundary of San Carlos Airport shall be compatible with the Aircraft Noise/Land Use Compatibility Standards found at page 8 of the 1981 San Mateo County Airport Land

Use Plan. The "Planning Boundary" for the San Carlos Airport is considered the ground area encompassed by the combination of the line depicting the 55 CNEL Noise Contour.

N-6: Refer all amendments to the Noise Element to the Airport Land Use Commission for a determination of consistency with the Airport Land Use Plan.

N-7: Take appropriate steps to reduce noise impacts to residents living near the San Carlos Airport and major arterials, particularly the Bayshore Freeway..

Table 4 REDWOOD CITY NOISE GUIDELINES FOR LAND USE PLANNING

Generalized Land Use	CNEL Range	General Land Use Recommendation
Residential and Educational	Less than 55	Satisfactory, with little noise impact and requiring no special noise insulation for new construction.
	55 to 60	New construction or development should be undertaken only after an analysis of noise reduction requirement is made and needed noise insulation features included in the design.
	Greater than 60	New construction or development should not be undertaken
Commercial	Less than 70	Satisfactory, with little noise impact and requiring no special noise insulation for new construction.
	70 to 80	New construction or development should be undertaken only after an analysis of noise reduction requirement is made and needed noise insulation features included in the design.
	Greater than 80	New construction or development should not be undertaken unless related to airport activities or services. Conventional construction will generally be inadequate, and special noise insulation features should be included in construction.
Industrial	Less than 75	Satisfactory, with little noise impact and requiring no special noise insulation for new construction.
	75 to 85	New construction or development should be undertaken only after an analysis of noise reduction requirement is made and needed noise insulation features included in the design.
	Greater than 85	New construction or development should not be undertaken unless related to airport activities or services. Conventional construction will generally be inadequate, and special noise insulation features should be included in construction.

Open	Less than 75	Satisfactory, with little noise impact and requiring no special noise insulation for new construction.
	Greater than 75	Land uses involving concentrations of people (spectator sports and some recreational facilities) or of animals (livestock farming and animal breeding) should generally be avoided.

SOURCE: Redwood City Strategic General Plan, *Noise Element,* page 11-14, adopted 1990.

Redwood City Noise Ordinance

Chapter 24 (Noise Regulation) of the Redwood City Municipal Code sets allowable noise limits for different types of receiving land uses. The noise levels allowed by the Noise Ordinance depend primarily on the background noise level in the area. Applicable noise limits are discussed in Chapter 24, Article II, Division 2 and 3. Chapter 24 provides specific guidance on acceptable noise level increases related to group assemblies/parties, construction, operation of machinery, and other noisy activities in residential areas. [1]

Federal Transit Administration (FTA) Vibration Impact Assessment Criteria

The City of Redwood City has not established vibration limits that can be used to evaluate the compatibility of sensitive land uses with respect to groundborne vibration. Although there are no local standards, the U.S. Department of Transportation's Federal Transit Administration (FTA) has developed vibration impact assessment criteria for evaluating vibration impacts associated with

[1] Section 24.21 prohibits noise increases of 6 decibels above local ambient measured noise at any point within a residential district due to an assemblage of 3 or more people during the hours of 8:00 pm and 8:00 am.

Section 24.30 of the Noise Ordinance establishes that noise levels generated by construction are prohibited between the hours of 8:00 pm and 7:00 am weekdays, or at any time on Saturdays, Sundays and holidays. In addition, Section 24.31 of the Ordinance prohibits noise levels from exceeding 110 dBA for any item of machinery, equipment, or device used during construction in a residential district.

transit projects, as shown in Table 5.[2] FTA's vibration impact criteria prescribe vibration levels for frequent events (more than 70 events of the same source per day), occasional events (30 to 70 vibration events of the same source per day), and infrequent events (less than 30 vibration events of the same source per day).

[2]U.S. Department of Transportation, Federal Transit Administration, Transit Noise and Vibration Impact Assessment, May 2006, FTA-VA-90-1003-06.

TABLE 5 Groundborne Vibration Impact Criteria

Land Use Category	Groundborne Vibration Impact Levels (VdB re 1 µinch/sec, RMS)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1 Buildings where vibration would interfere with interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2 Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB
Category 3 Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB

Notes:

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3. "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration sensitive manufacturing or research should always require detailed evaluation to define the acceptable vibration levels. Ensuring low vibration levels in a building requires special design of HVAC systems and stiffened floors.

Source: U.S. Department of Transportation, Federal Transit Administration, Transit Noise and Vibration Impact Assessment, May 2006, FTA-VA-90-1003-06.

EXISTING CONDITIONS

The most significant noise sources in the City of Redwood City are transportation-related, including vehicular traffic, aircraft, and railroads. Other noise sources such as industry, mechanical equipment on buildings, and recreational activities contribute, although to a lesser degree, at particular locations throughout the City.

Local traffic is the most significant source of community noise in the City because it occurs virtually everywhere and the sources are in close proximity to the sensitive receptors. Freeways can affect larger geographical areas because of the high volumes of traffic and high speeds. Railroad trains are the source of the highest regularly occurring instantaneous maximum noise levels in the community. Additional sources of noise include site-specific and stationary sources such as construction, and other commercial and industrial activities.

Noise Measurements

A comprehensive noise monitoring survey was made for this update during the month of July 2008. The sites for measurements were selected to provide information on the distribution of noise levels along the streets and highways, to determine the level of baseline ambient noise levels in the quiet residential areas of the City away from identifiable noise sources, to measure noise levels generated by railroads, and to measure noise generated by stationary sources.

Based on familiarity gained through numerous project-specific noise studies prepared in Redwood City, a review of aerial photos, and discussions with City Staff, 11 long-term noise measurement sites (minimum 48 hours) and 14 short-term noise measurement sites (10-minute duration) were identified. Figure 1A shows the noise measurement locations. Appendix 1 presents the daily trend in noise levels for the long-term noise measurements. Illingworth & Rodkin, Inc. files were also reviewed for recent projects (labeled in red in Figure 1A) where noise data, collected since 2005, were appropriate for inclusion into the General Plan Update Monitoring Program. Table 6 summarizes the long-term noise measurement results. Table 7 summarizes the short-term noise measurement results.

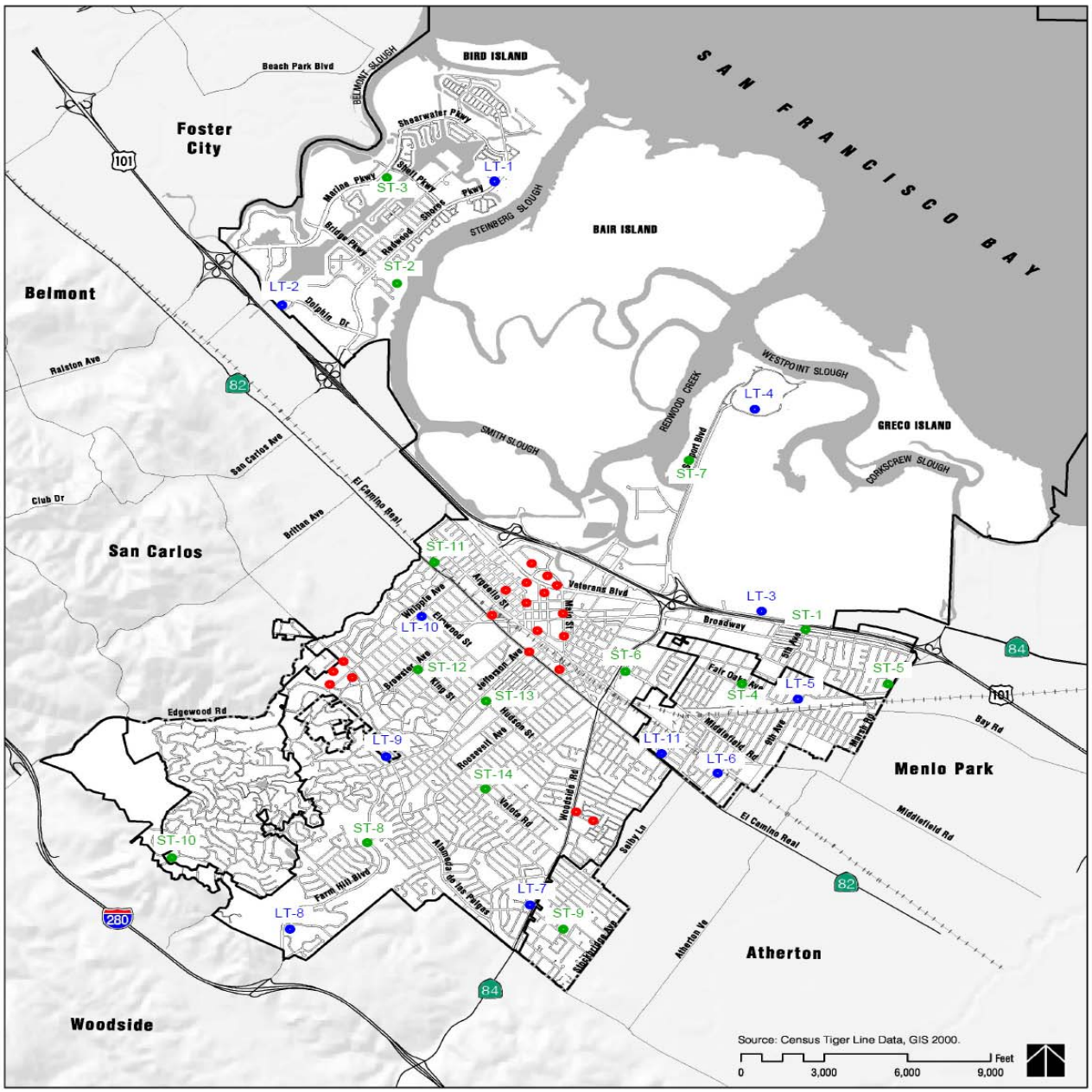


Figure 1A: Noise Measurement Locations

State Highways

Highway 101 and Interstate 280 (US-101, I-280 respectively), El Camino Real (SR-82), Woodside Road (SR-84), US-101 is the major north-south transportation corridor transecting the City. I-280 is located within the southwestern portion of the City. SR-84 provides access to San Gregario to the west. SR-82 provides access to San Mateo located to the north, and to Atherton located to the south.

Noise measurements were made adjacent to US-101 at sites LT-2, LT-3, and ST-1. Existing noise levels adjacent to the highway are approximately 67-76 dBA CNEL. Highway traffic noise levels vary dramatically depending on the proximity of the receiver to the highway and presence or lack of shielding. Noise measurement LT-8 was made adjacent to I-280. Noise levels are approximately 62-64 dBA CNEL. Noise measurement LT-7 was located on the west side of SR-84. The average noise level at this location was calculated to be 67-70 dBA CNEL. Noise measurement site LT-11 was made along SR-82 south of Woodside Road where noise levels were approximately 70-73 dBA CNEL.

Local Arterial Roadways

Whipple Avenue, Alameda de Las Pulgas, Jefferson Avenue, Redwood Shore Parkway, Marine Parkway, and Seaport Boulevard are the major local roadways in the City of Redwood City. Measurements at locations LT-1, LT-9, and LT-10 show existing noise levels in residential areas near these major arterial roadways typically range from about 60-70 dBA CNEL.

Railroads

Railroads are a significant source of transportation-related noise and vibration in Redwood City. Noise measurements made at Sites LT-5 and LT-6 provided the daily average noise levels and the instantaneous maximum noise levels resulting from train passbys, near grade crossings where railroad train horns are normally sounded, and away from grade crossings. Average daily noise levels along the railroad lines ranged from 61-70 dBA CNEL. Maximum noise levels from train passbys ranged from 85 to 95 dBA at 40 feet from the near track at Site LT-6. Near at-grade crossings, where train-warning whistles are sounded to warn pedestrians and motorists of on-coming trains, maximum noise levels range from about 90 to 100 dBA at 40 feet from the near track.

Ground-borne vibration occurs in areas adjacent to fixed rail lines when railroad trains pass through Redwood City. Ground vibration levels along the railroad corridors are proportional to the speed and weight of the trains as well as the

condition of the tracks and train engine and car wheels. Typically, the setback to the 72 VdB contour is 100 feet or greater from the center of the near track. Vibration measurements conducted in San Carlos[3] indicate that the 72 VdB contour distances were about 65 feet from the center of the near railroad track for the maximum measured train vibration level and about 55 feet from the center of the near railroad track for typical train passbys.

Aircraft

Aircraft operations in the vicinity of the San Carlos Airport are also a significant source of noise within the City. Noise measurements were attempted in the vicinity of the Airport during the noise monitoring survey, but were not completed at the request of airport security officials. Noise data contained in the 1996 San Mateo County Comprehensive Airport Land Use Plan (CLUP) were then reviewed to identify areas where aircraft noise levels would exceed those considered compatible with noise-sensitive development. The projected 1995 noise contours for the airport are shown in Figure 1B.

An Avigation Easement Review Area is established in the CLUP identifying the geographic area where aircraft noise exceeds 55 dBA CNEL. The Airport Land Use Commission requests that local agencies grant an avigation easement to the County of San Mateo when sensitive developments are proposed within the airport's 55 dBA CNEL noise contour.

[3] San Carlos Train Depot Site Noise and Vibration Assessment, Illingworth & Rodkin, Inc., August 8, 2006.

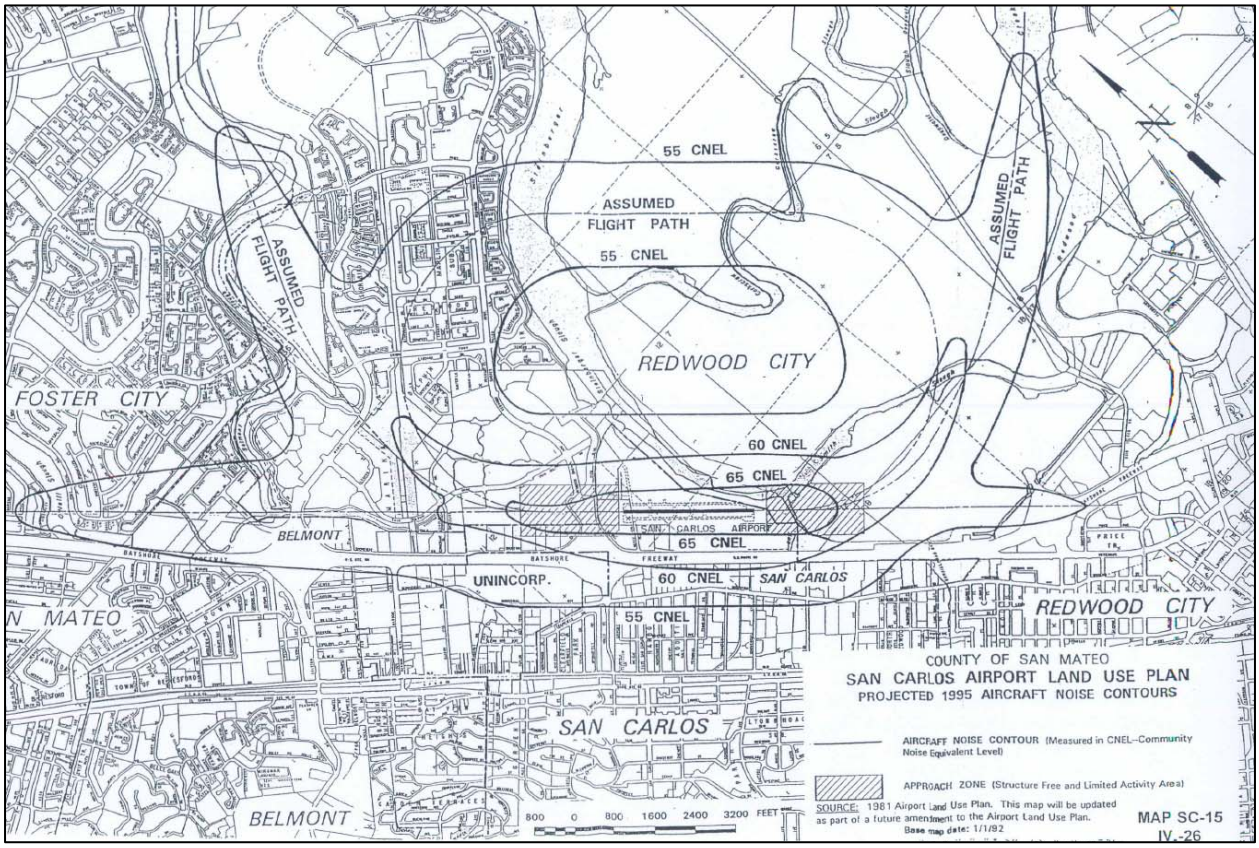


Figure 1B: San Carlos Airport Noise Contours (1995)

Other Noise Sources

Noise sources that affect sensitive receptors within the community include industrial land uses or those normally associated with and/or secondary to residential development. These include gas stations, car washes, fire stations, air conditioning units, swimming pool pumps, school playgrounds, and public parks. Another source of noise in Redwood City relates to intermittent construction activities. Construction noise can be significant for short periods of time at any particular location as a result of public improvement projects, private development projects, remodeling, etc. The implementation of standard controls, through the environmental review and permitting process, is used to regulate construction noise.

Preliminary Considerations

Ground transportation is and is expected to continue to be the dominant source of noise in Redwood City. There is currently research ongoing on the effects of different type of pavement surfaces on the noise generated by vehicular traffic. The interaction of tires and pavement is the main source of traffic noise. The City of Redwood City has no jurisdiction over the noise generated by automobiles, the types of tires drivers select, etc., but the City can select the type of pavement that it uses to repave its streets. One recent study in San Rafael showed a 3 to 5 decibel reduction in vehicular traffic noise could be achieved when repaving a street in relatively poor condition with a "quiet" pavement such as open-grade asphalt concrete or rubberized asphalt[4]. The consideration of quiet pavement surfaces in the City's repaving plans provides an opportunity to make a noticeable reduction in traffic noise along City streets.

The New General Plan is contemplating mixed use development in several locations along arterial streets, such as El Camino Real and Woodside Road. Calculated noise levels along these streets currently exceed the City's existing noise and land use compatibility guidelines for residential uses. Specifically, the land use compatibility guidelines state that where average noise levels exceed 60 dBA CNEL, new residential uses "should not be undertaken." The current land use compatibility guidelines provide a single, City-wide standard, which does not appear to reflect the complexity of development across the City. The 60 dBA CNEL standard would continue to be appropriate for existing single-family neighborhoods and other places within the City where suburban or semi-rural noise levels are desired. Along arterials and railroad tracks, however, the City may wish to consider a more flexible standard that takes into account the

[4] *Noise Evaluation of the Pavement Rehabilitation on the 4th Street "Miracle Mile"*, Paul R. Donavan, Sc.D., Illingworth & Rodkin, Inc., December 2003.

existing and projected future noise environment. Notably, these guidelines address *outdoor* noise levels. In the State of California, interior residential noise levels are regulated at the state level, by Title 24 of the California Code of Regulations. Specifically, Title 24 stipulates a maximum of 45 dBA CNEL for interior residential noise levels. In loud environments, insulation, double or triple pane windows, and special ventilation systems are among the tools used to achieve acceptable interior noise levels.

Placing residents in proximity to non-residential land uses can result in isolated noise problems. For instance, outdoor music played at outdoor dining areas or bars can annoy adjacent residences and be a source of ongoing complaints. Other urban noise sources, such as the collection of large garbage dumpsters early in the morning, the noise of heating, ventilating, and air conditioning equipment, and outdoor maintenance activities, are all more frequent in an urban setting. The purpose for a quantitative noise ordinance is to address these types of issues. The review and update applicable City ordinances is something the City could consider in the future if the change in land use patterns results in conflicts, which cannot be resolved through existing regulations.

In order to address noise issues more effectively in the future, the City may wish to set forth new policies and more important, more specific and effective action measures within the New General Plan. Some ideas are listed below for further consideration by the City's policy makers.

Noise/Land Use Compatibility Measures

- Consider adding flexibility to the City's land use compatibility guidelines to help foster mixed use development along arterials and in the proximity of railroads.
- Help to educate the construction and development community about noise insulation/attenuation techniques in new residential construction.
- Develop/refine standard disclosure statements that would be document existing exterior noise sources in new mixed use development along arterials and railroads.
- Consider adoption of vibration standards and codify acceptable levels within the City.

Nuisance Noise Measures

- Consider requiring that all building permit applicants sign a form acknowledging requirements of the City's noise ordinance. Develop easy-to-read educational brochures about the noise ordinance in multiple languages.

- Consider the possible restriction of certain types of HVAC and/or maintenance equipment (such as leaf blowers) within the City.
- Ensure appropriate enforcement of all noise regulations, including cash fines for violations.
- Provide appropriate funding for City personnel to monitor noise levels and investigate noise complaints.
- Provide education to the community at large about the importance of maintaining a healthy noise environment and identify ways residents can assist in noise abatement efforts.
- Develop and/or refine a tracking/monitoring system of noise complaints within the City such that repeat offenders might be more easily identified.
- Encourage the enforcement of State of California motor vehicle noise standards for cars, trucks, and motorcycles with the California Highway Patrol and the City's Police Department.

City Practices

- Include noise considerations in evaluating City purchases of noise generating equipment (vehicles, motorized maintenance equipment, etc.), giving priority where practicable to purchase items incorporating all available noise control technology.

Vibration

Illingworth & Rodkin is not aware of any Bay Area city that has adopted FTA's vibration criteria. However, Illingworth has found that acoustical consultants will typically utilize these criteria in project-specific analyses where vibration impacts are anticipated.

Vibration levels are site specific and depend on several variables, including soil conditions, the type, load, and speed of trains, track construction, and the conditions of tracks/train wheels. Vibration effects will increase with soils that are weak or soft, which includes the "bay mud" characteristic of the northern and eastern portions of Redwood City. Vibration is most effectively mitigated through land use planning. A setback of 100 feet is generally sufficient for vibration-sensitive development in the Bay Area. Other vibration reduction techniques, including the development of trenches, heavier foundations for buildings, and stiffer flooring materials have been used in other regions and outside the US to control train vibration, but setbacks are much more commonly utilized in California and the rest of the U.S.

The 2008 Program EIR for the proposed California High Speed Rail between San Francisco and the Central Valley identified the San Francisco/Transbay Terminal

to the Dumbarton Bridge corridor as having the potential for moderate to high vibration impacts, owing primarily to the proximity of existing residential dwellings to the proposed alignment. The EIR further stipulates that additional, site-specific analyses would be required to more precisely determine potential vibration effects and appropriate mitigation along new high-speed rail corridors. As a policy matter, the City may wish to require any potential vibration-sensitive developments proposed for the immediate high-speed rail corridor consider both existing and reasonably foreseeable future vibration levels as part of the environmental review process.

TABLE 6: Long-Term Noise Measurement Results

Measurement Location, Time Period, Date	Measured Noise Levels, dBA				Calculated CNEL, dBA	Primary Noise Source
	L_{eq}	L_{10}	L_{50}	L_{90}		
LT-1 – About 25 feet from the Centerline of Redwood Shores. Daytime (7:00 am-10:00 pm) noise level range. (07/10/08-07/14/08)	56-78	65-89	46-60	39-53	62 - 67	Redwood Shores
LT-1 – About 25 feet from the Center of Redwood Shores. Nighttime (10:00 pm-7:00 am) noise level range.	47-61	47-64	41-51	39-47		Redwood Shores
LT-2 – At 1399 Shoreway Road, ~150 feet from the edge of US-101. Daytime noise level range. (07/10/08-07/14/08).	65-76	67-75	64-73	62-71	74-76	US-101
LT-2 – At 1399 Shoreway Road, ~150 feet from the edge of US-101. Nighttime noise level range.	61-72	65-74	60-72	54-70		US-101
LT-3 – In the parking lot of mobile homes at 3015 East Bay Shore Road, ~100 feet from the edge of US-101. Daytime noise level range. (07/10/08-07/14/08).	59-72	61-73	57-67	54-62	67-72	US-101
LT-3 – In the parking lot of mobile homes at 3015 East Bay Shore Road, ~100 feet from the edge of US-101. Nighttime noise level range.	54-72	56-73	51-66	45-63		US-101
LT-4 – In the parking lot of Seaport Center. Daytime noise level range. (07/16/08-07/18/08).	53-65	55-67	52-64	50-61	62	Seaport Boulevard
LT-4 – In the parking lot of Seaport Center. Nighttime noise level range.	49-60	50-61	47-60	45-58		Seaport Boulevard
LT-5 – Fair Oaks Avenue between 7th Avenue and 8th Avenue across from Caltrain Station. Daytime noise level range. (07/16/08-07/18/08).	54-66	54-66	46-58	44-55	61	UPRR/ Fair Oaks Avenue
LT-5 – Fair Oaks Avenue between 7th Avenue and 8th Avenue across from Caltrain Station. Nighttime noise level range.	41-63	39-61	38-46	36-43		UPRR/ Fair Oaks Avenue
LT-6 – On Glendale Avenue between Amherst Avenue and 5th Avenue across from Caltrain Station. Daytime noise level range. (07/16/08-07/18/08).	59-71	51-61	48-58	45-55	69-70	UPRR/ distant traffic
LT-6 – Glendale Avenue between Amherst Avenue and 5th Avenue across from Caltrain Station. Nighttime noise level range.	40-68	41-54	36-48	35-44		UPRR/ distant traffic
LT-7 – 30 feet from the Center of Woodside Road. Daytime noise level range. (07/18/2008-07/22/2008).	61-72	65-73	56-69	43-64	67-70	Woodside Road
LT-7 – 30 feet from the Center of Woodside Road. Nighttime noise level range.	50-67	46-70	34-63	32-51		Woodside Road
LT-8 – 45 feet from the center of Farm Hill Boulevard. Daytime noise level range. (07/18/08-07/22/08).	56-66	59-69	39-64	32-56	62-64	Farm Hill Boulevard and Distant Traffic
LT-8 – 45 feet from the center of Farm Hill Boulevard. Nighttime noise level range.	42-60	26-65	24-53	23-43		Farm Hill Boulevard / distant traffic
LT-9 – 20 feet from the center of Alameda de Las Pulgas, ~30 feet from the edge of James Avenue. Daytime noise level range. (07/23/08-07/28/08).	57-66	59-70	41-64	38-52	64-66	Alameda de Las Pulgas
LT-9 – 20 feet from the center of Alameda de Las Pulgas, ~30 feet from the edge of James Avenue. Nighttime noise level range.	43-61	37-65	36-51	36-43		Alameda de Las Pulgas
LT-10 – Front of 1503 Whipple Avenue, about 25 feet from the center of the road. Daytime noise level range. (07/23/08-07/28/08).	62-71	67-72	50-68	41-61	68-70	Whipple Avenue

TABLE 6: Long-Term Noise Measurement Results						
Measurement Location, Time Period, Date	**Measured Noise Levels, dBA**				**Calculated**	**Primary Noise**
	L_{eq}	L_{10}	L_{50}	L_{90}		
LT-10 – Front of 1503 Whipple Avenue, about 25 feet from the center of the road. Nighttime noise level range. (07/23/08-07/28/08).	52-66	41-70	30-60	28-48		Whipple Avenue
LT-11 – 25 feet from the Center of El Camino Real, South of Woodside Boulevard. Daytime noise level range. (07/23/08-07/28/08).	64-75	68-77	59-69	49-62	70-73	El Camino Real.
LT-11 – 25 feet from the Center of El Camino Real, South of Woodside Boulevard. Nighttime noise level range. (07/23/08-07/28/08).	55-69	57-72	44-63	41-56		El Camino Real

Table 7: Short-Term Noise Measurement Results						
Measurement Location and Time	**Measured Noise Levels, dBA**				**Estimated CNEL, dBA**	**Primary Noise Source**
	L_{eq}	L_{10}	L_{50}	L_{90}		
ST-1 – In front of 3232 Rolison Road, ~15 feet from the Center of the road. (07/10/08, 2:56 to 3:06 pm)	68	71	64	62	70	US-101/ Rolison Road
ST-2 – On Bridge Parkway, ~75 feet from the Center of Redwood Shores. (07/10/08, 3:28 to 3:38 pm)	62	64	57	51	66	Redwood Shores
ST-3 – About 25 from the Center of Marine Parkway, and ~200 feet from the Edge of Shell Parkway. (07/10/08, 4:00 to 4:10 pm)	56	60	52	47	60	Marine Parkway
ST-4 – Fair Oaks Avenue, ~15 feet from the Center of the road. (07/15/08, 2:06 to 2:16 pm)	58	62	53	50	63	Fair Oaks Avenue
ST-5 – About 20 feet from the Center of Marsh Avenue, and about 100 feet from the edge of Florence Street. (07/15/08, 2:27 to 2:37 pm)	72	75	69	60	76	Marsh Avenue
ST-6 – About 25 feet from the Center of Middlefield Road. (07/15/08, 3:42 to 3:52 pm)	72	75	67	62	75	Woodside Road / Middlefield Road
ST-7 – About 30 feet from Center of Seaport Boulevard. (07/18/08, 11:03 to 11:13 am)	71	75	65	57	75	Trucks along portion of Seaport Boulevard
ST-8 – About 20 feet from the Center of Farm Hill Road near McGarvey Avenue. (07/18/08, 1:34 to 1:44 pm)	62	67	57	44	58	Farm Hill Road
ST-9 – On Santa Clara Avenue near Idyllwild Drive. (07/18/08, 2:05 to 2:15 pm)	61	63	46	40	61	Santa Clara Avenue
ST-10 – About 2000 feet from Highway 280, on Woodside Way near Glencrag Way. (07/23/08, 11:36 to 11:46 am)	49	47	43	41	49	Distant Traffic
ST-11 – 25 feet from the Center of El Camino Real near Claremont Street. (07/28/08, 10:32 to 10:42 am)	69	72	66	62	68	El Camino Real
ST-12 – Off Brewster Street, ~ 25 feet from the Center of the road, near King Street. (07/28/08, 10:59 to 11:09 am).	60	64	53	44	60	Brewster Street
ST-13 – Hudson Street between Jefferson Avenue and Madison Avenue. (07/28/08, 11:18 to 11:28 am)	63	68	55	46	63	Hudson Street
ST-14 – 15 feet from the Center of Valota Avenue between Redwood Avenue and Oak Avenue. (07/28/08, 11:38 to 11:48 am).	59	63	54	46	60	Hudson Street

Appendix 1

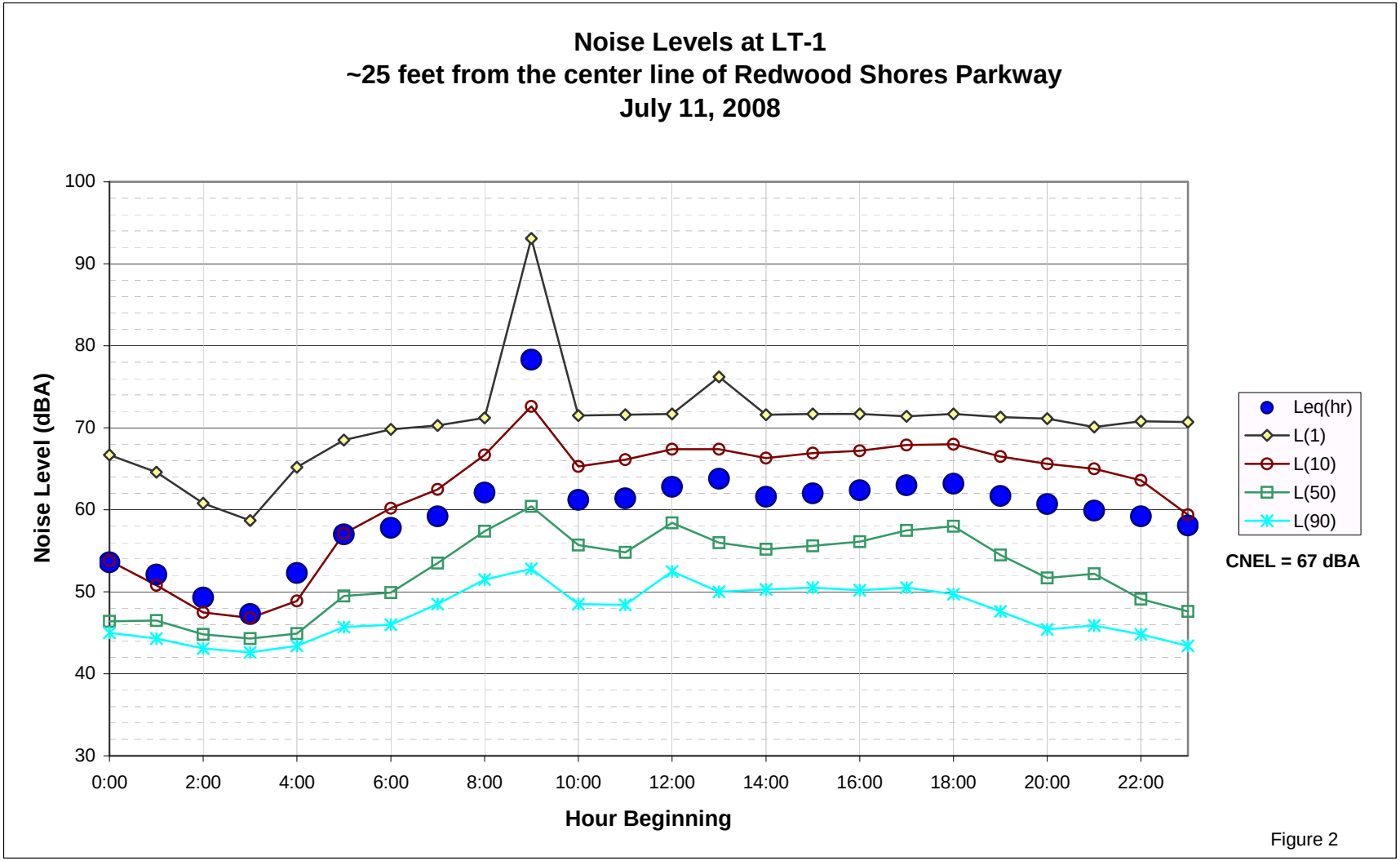

Noise Levels at LT-1
~25 feet from the center line of Redwood Shores Parkway
July 11, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 67 dBA

Figure 2

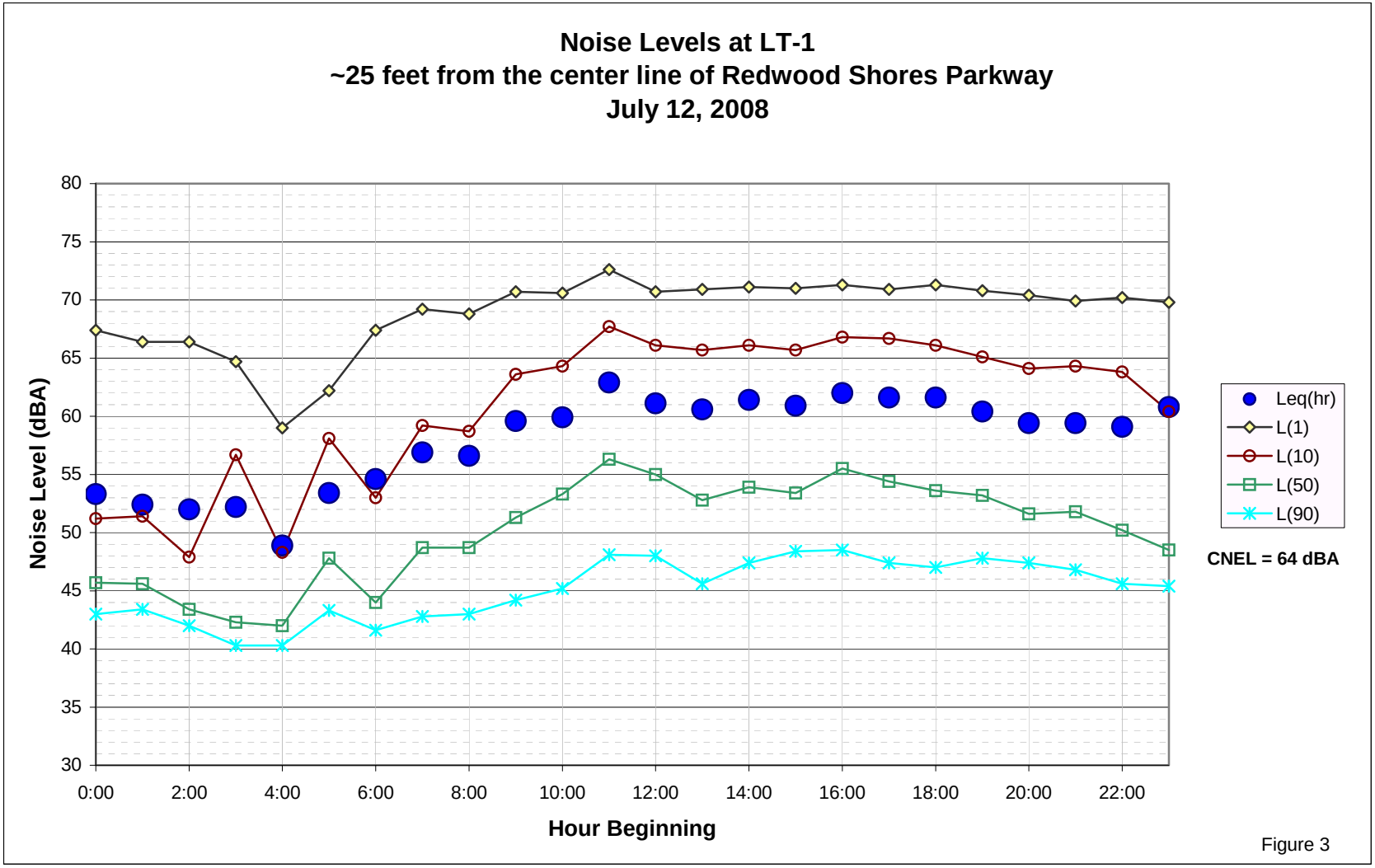

Noise Levels at LT-1
~25 feet from the center line of Redwood Shores Parkway
July 12, 2008
Noise Level (dBA)
80
75
70
65
60
55
50
45
40
35
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 64 dBA

Figure 3

Noise Levels at LT-1
~25 feet from the center line of Redwood Shores Parkway
July 13, 2008

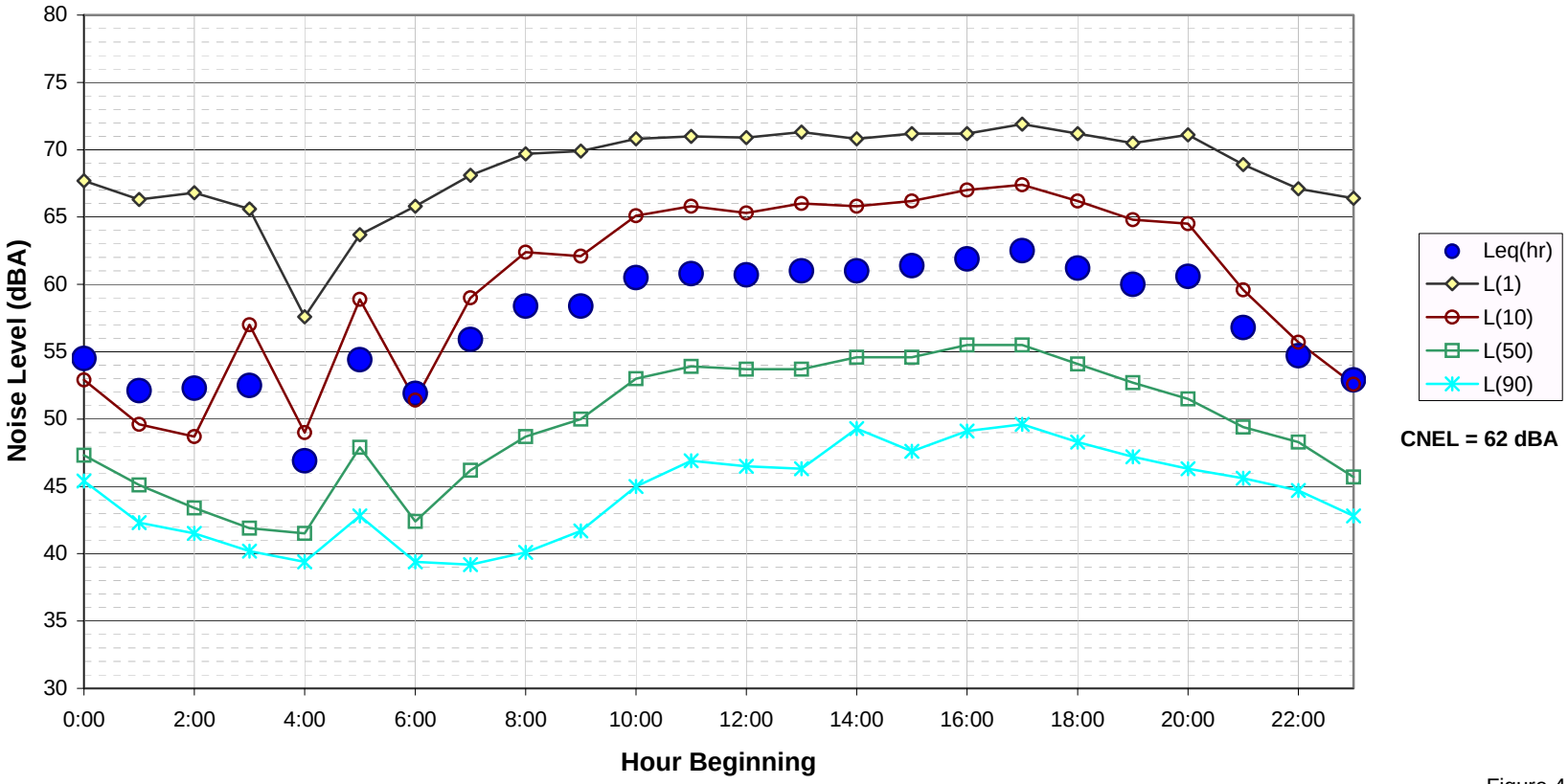


Figure 4

Noise Levels at LT-1
~25 feet from the center line of Redwood Shores Parkway
July 14, 2008

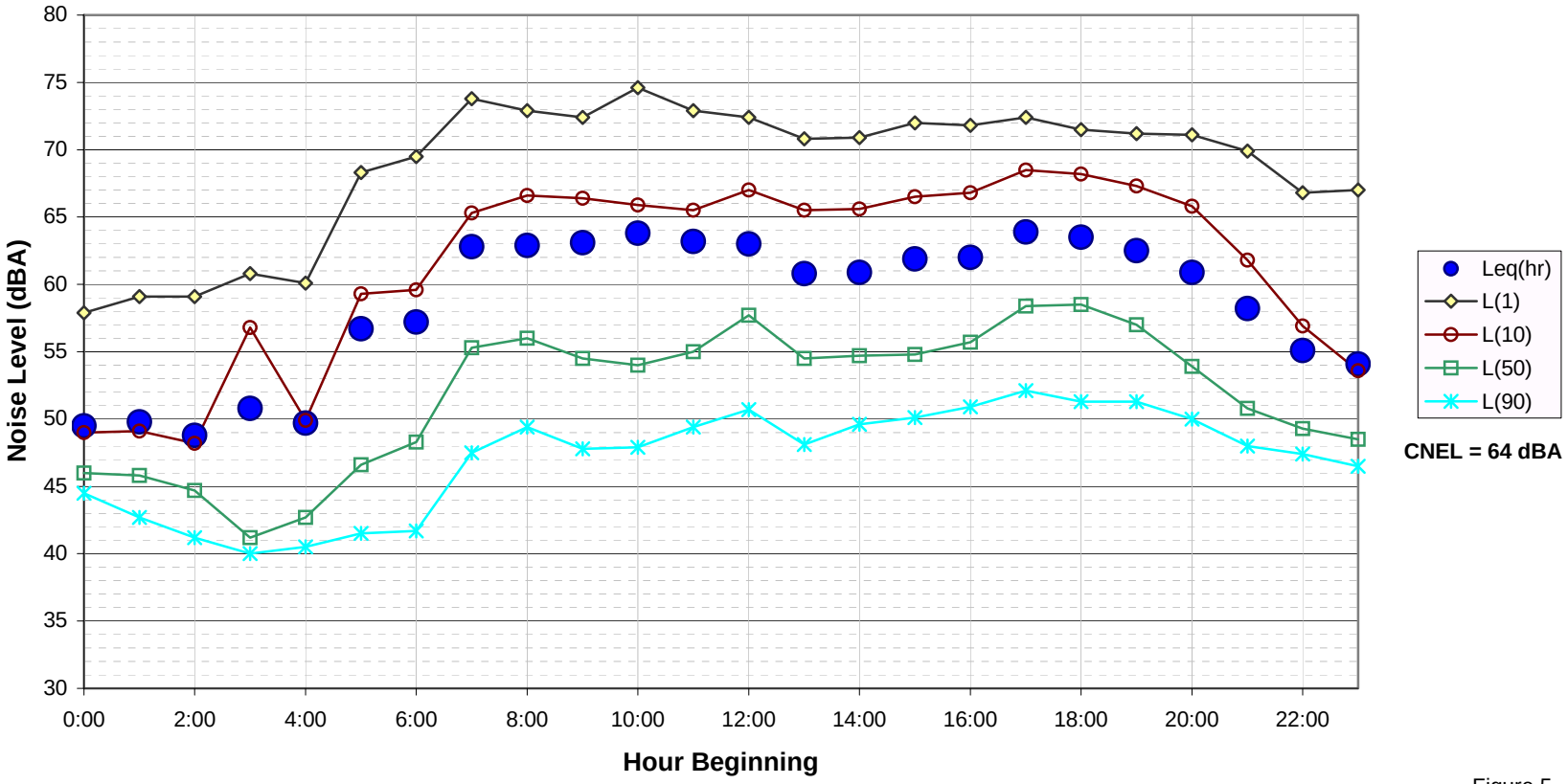


Figure 5

Noise Levels at LT-2
In the Parking Lot of 1399 Shoreway Road, ~150 feet from the edge of US-101
July 11, 2008

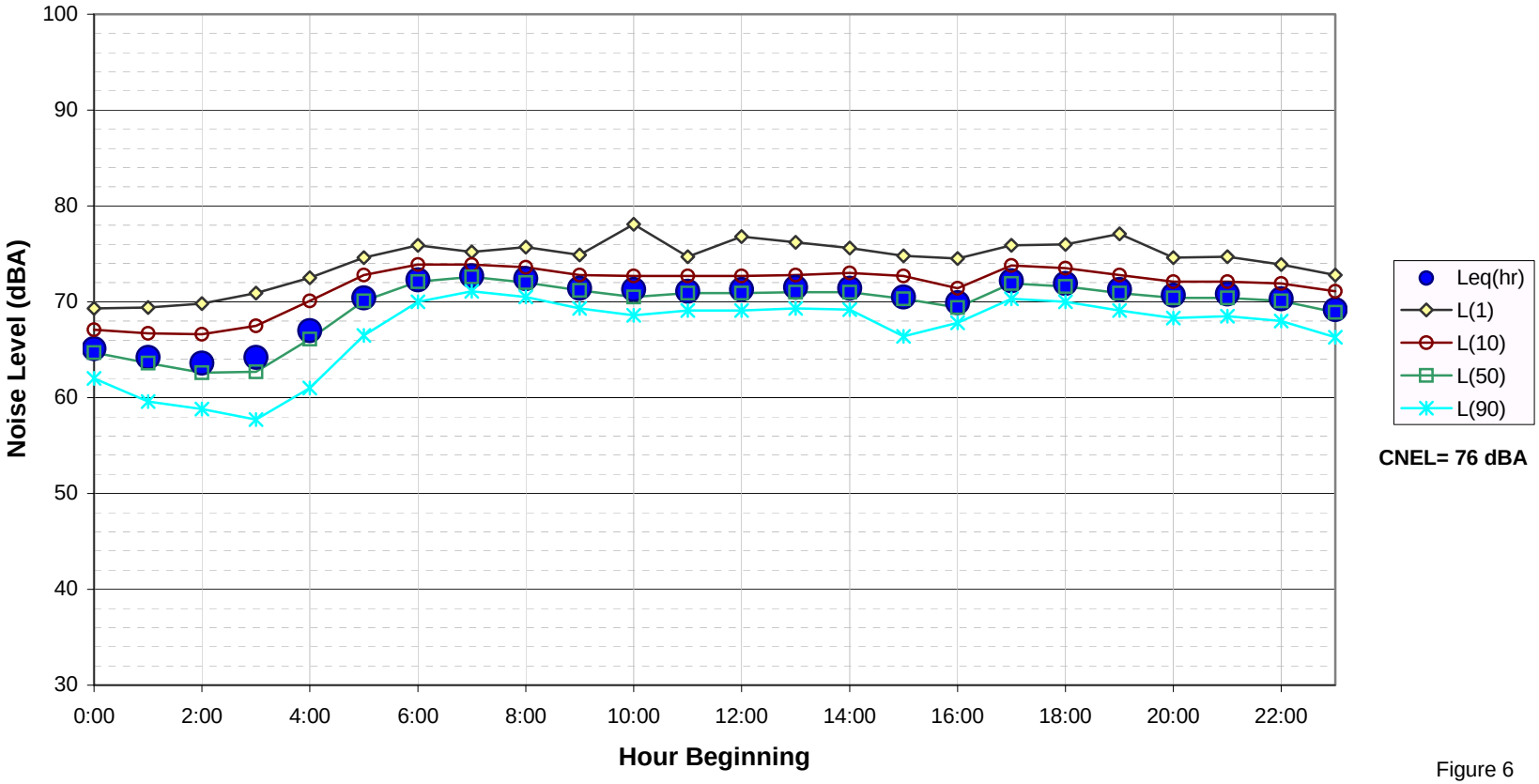


Figure 6

Noise Levels at LT-2
In the Parking Lot of 1399 Shoreway Road, ~150 feet from the edge of US-101
July 12, 2008

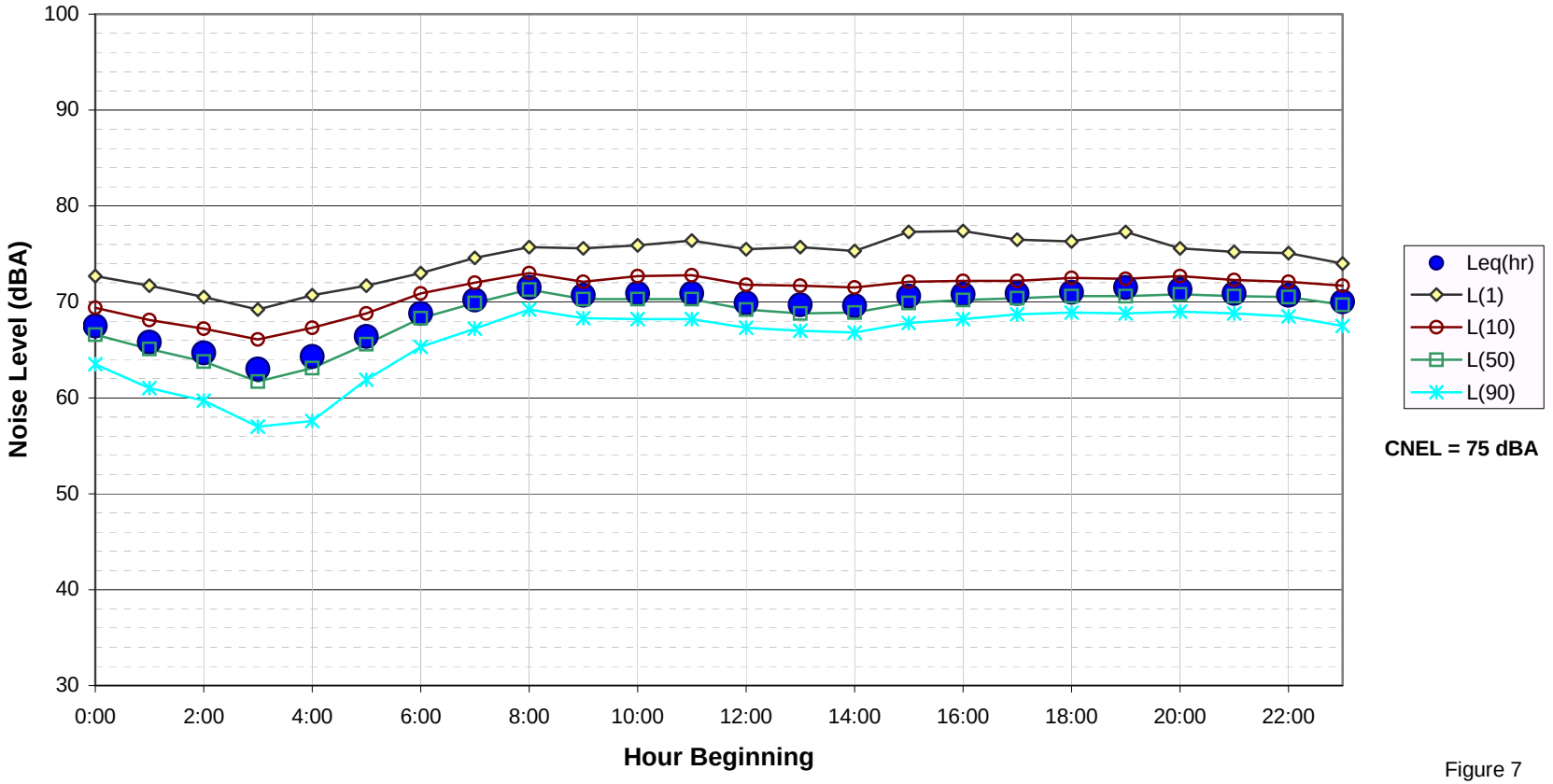
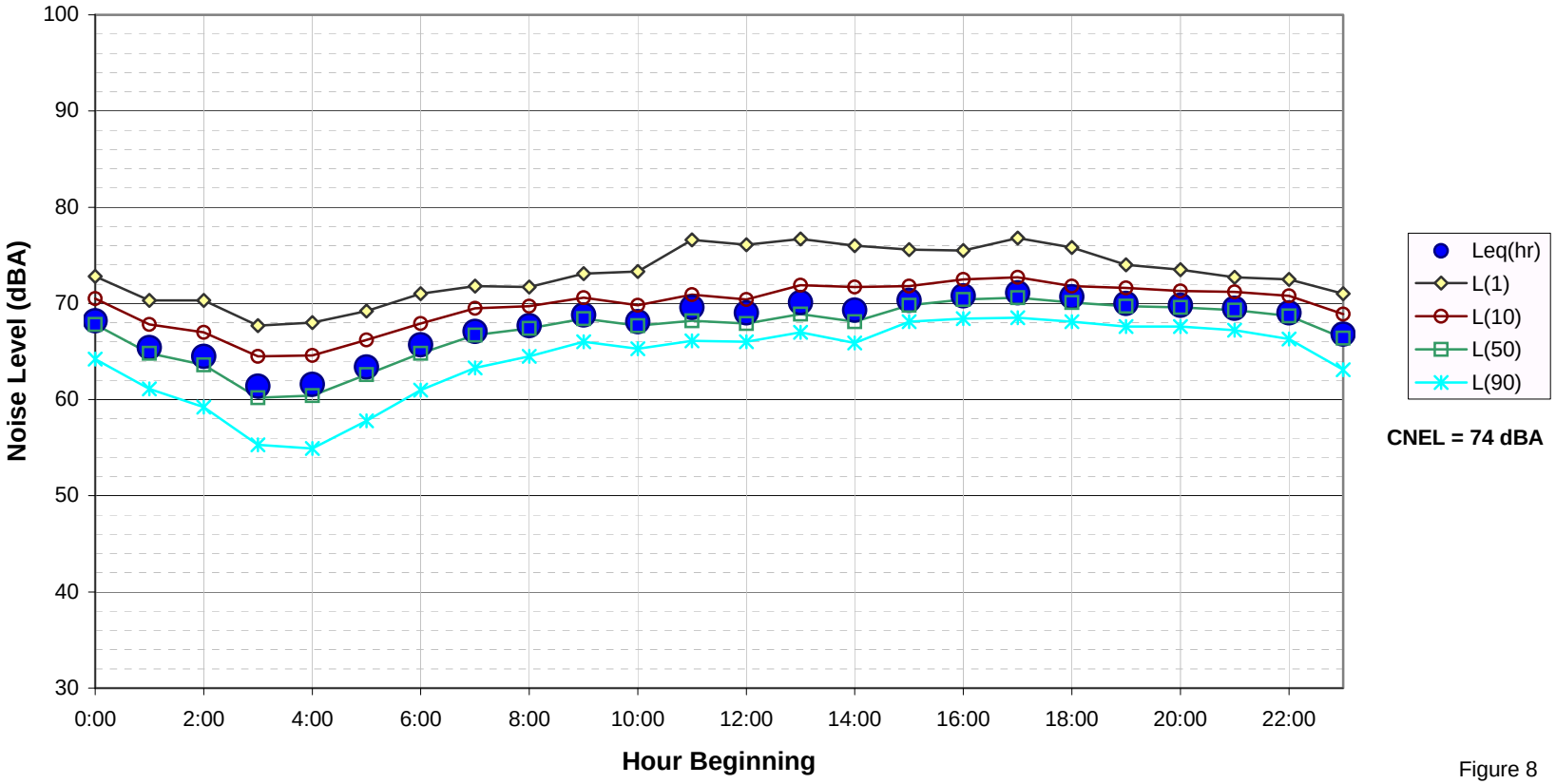


Figure 7

Noise Levels at LT-2
In the Parking Lot of 1399 Shoreway Road, ~150 feet from the edge of US-101
July 13, 2008



CNEL = 74 dBA

Figure 8

Noise Levels at LT-2
In the Parking Lot of 1399 Shoreway Road, ~150 feet from the edge of US-101
July 14, 2008

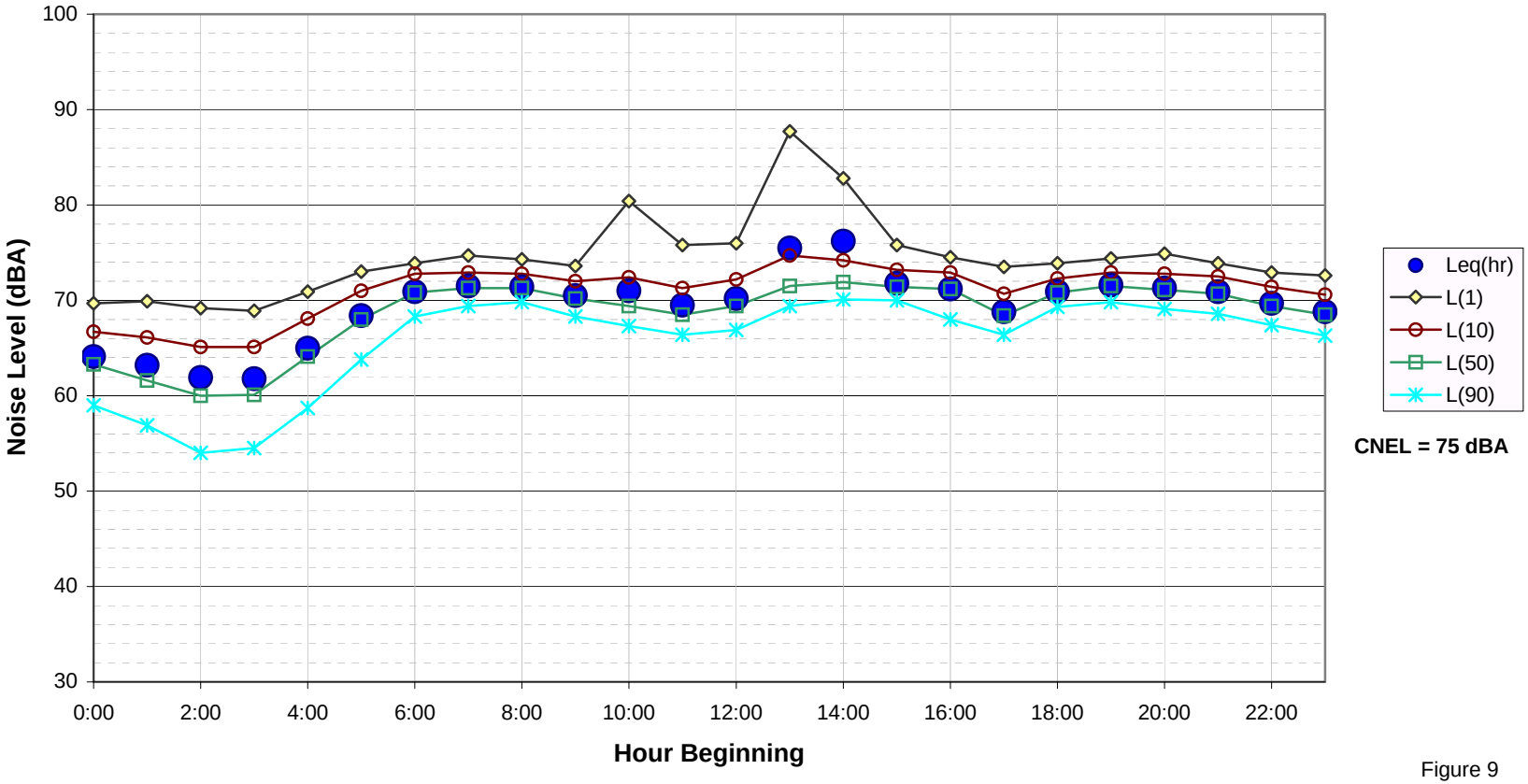
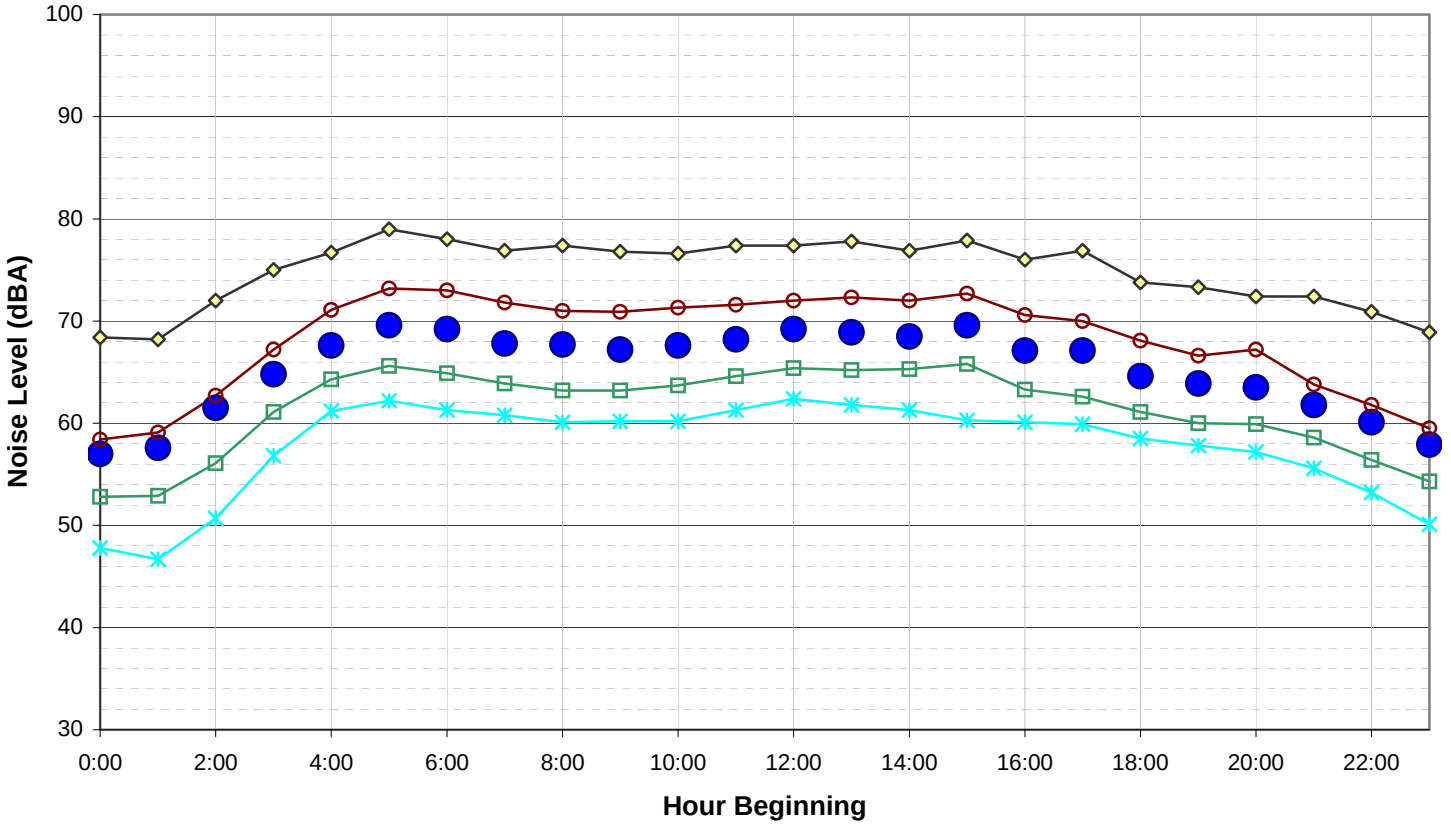


Figure 9

Noise Levels at LT-3
In the Parking Lot of 3015 East Bay Shore Road, ~100 feet from the edge of US-101
July 11, 2008



CNEL = 72 dBA

Figure 10

Noise Levels at LT-3
In the Parking Lot of 3015 East Bay Shore Road, ~100 feet from the edge of US-101
July 12, 2008

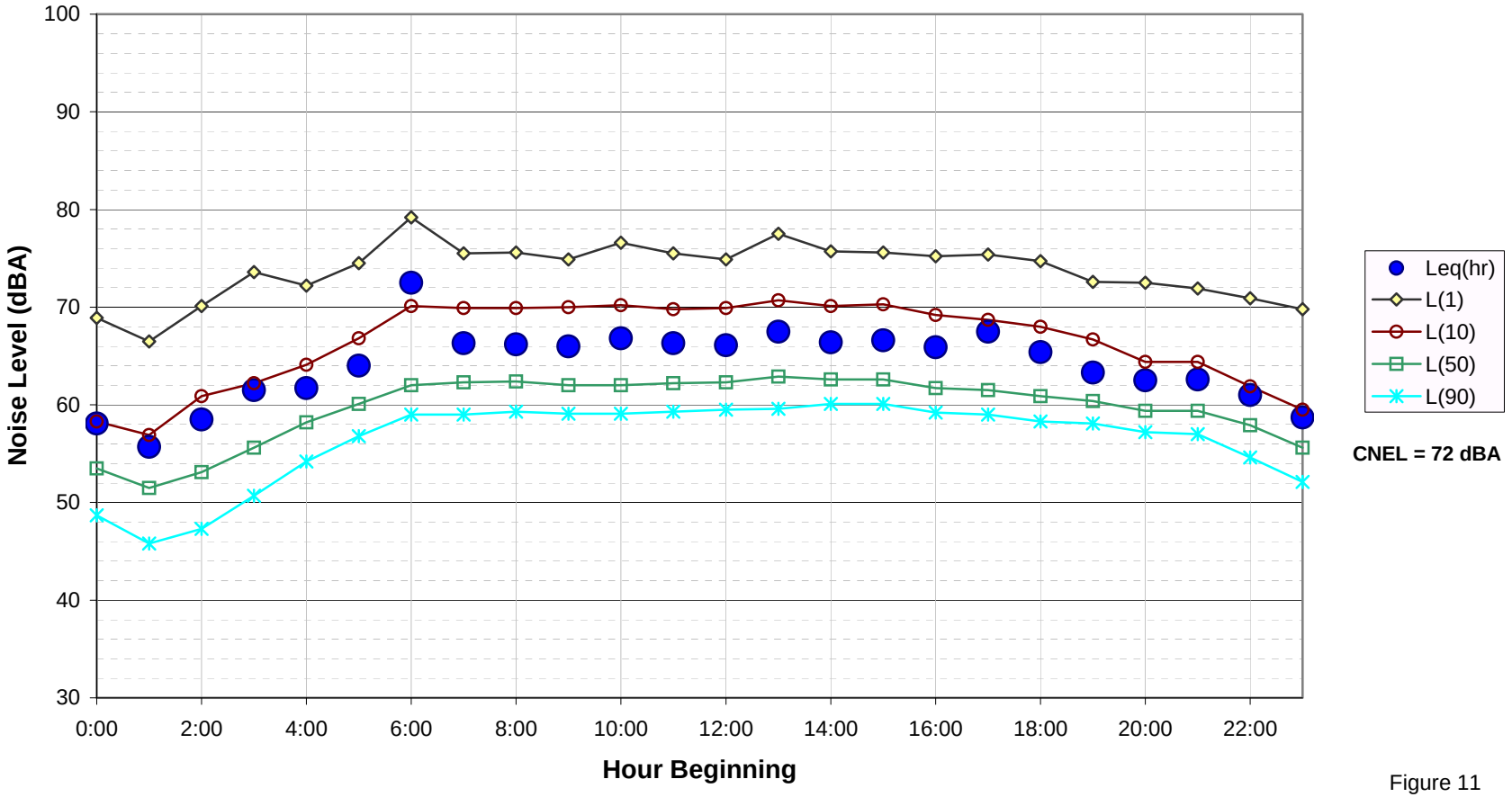
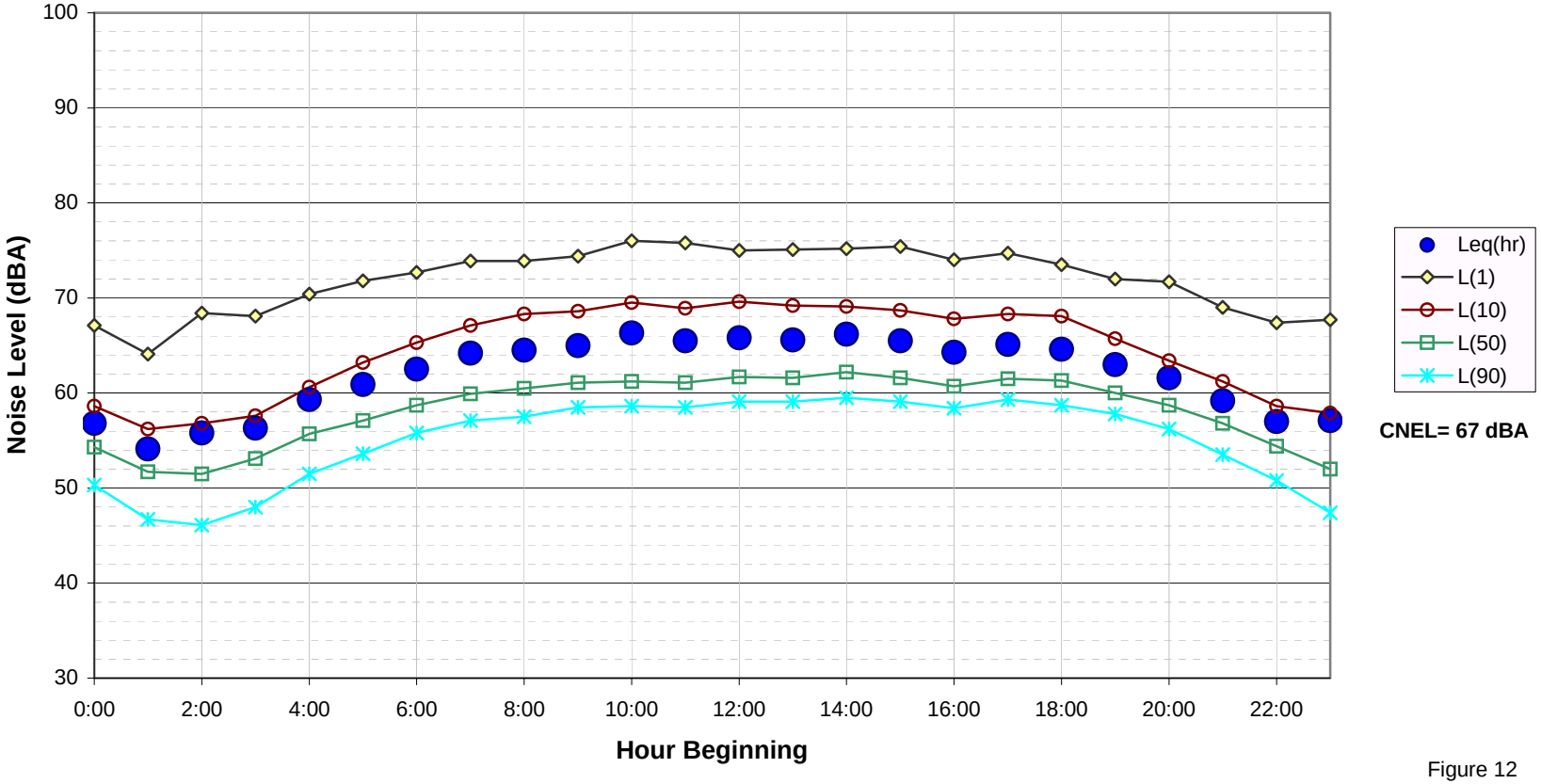


Figure 11

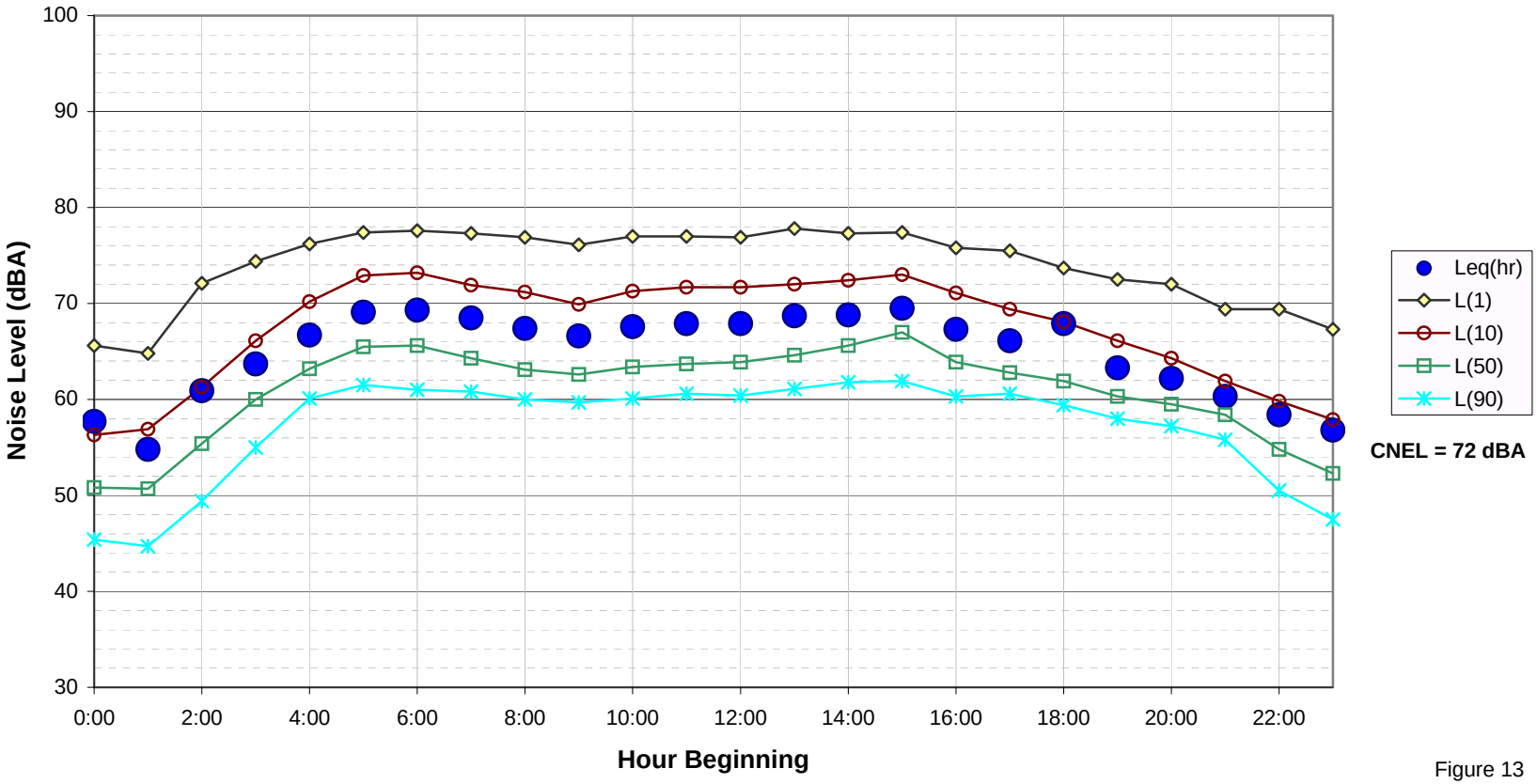
Noise Levels at LT-3
In the Parking Lot of 3015 East Bay Shore Road, ~100 feet from the edge of US-101
July 13, 2008



CNEL= 67 dBA

Figure 12

Noise Levels at LT-3
In the Parking Lot of 3015 East Bay Shore Road, ~100 feet from the edge of US-101
July 14, 2008



CNEL = 72 dBA

Figure 13

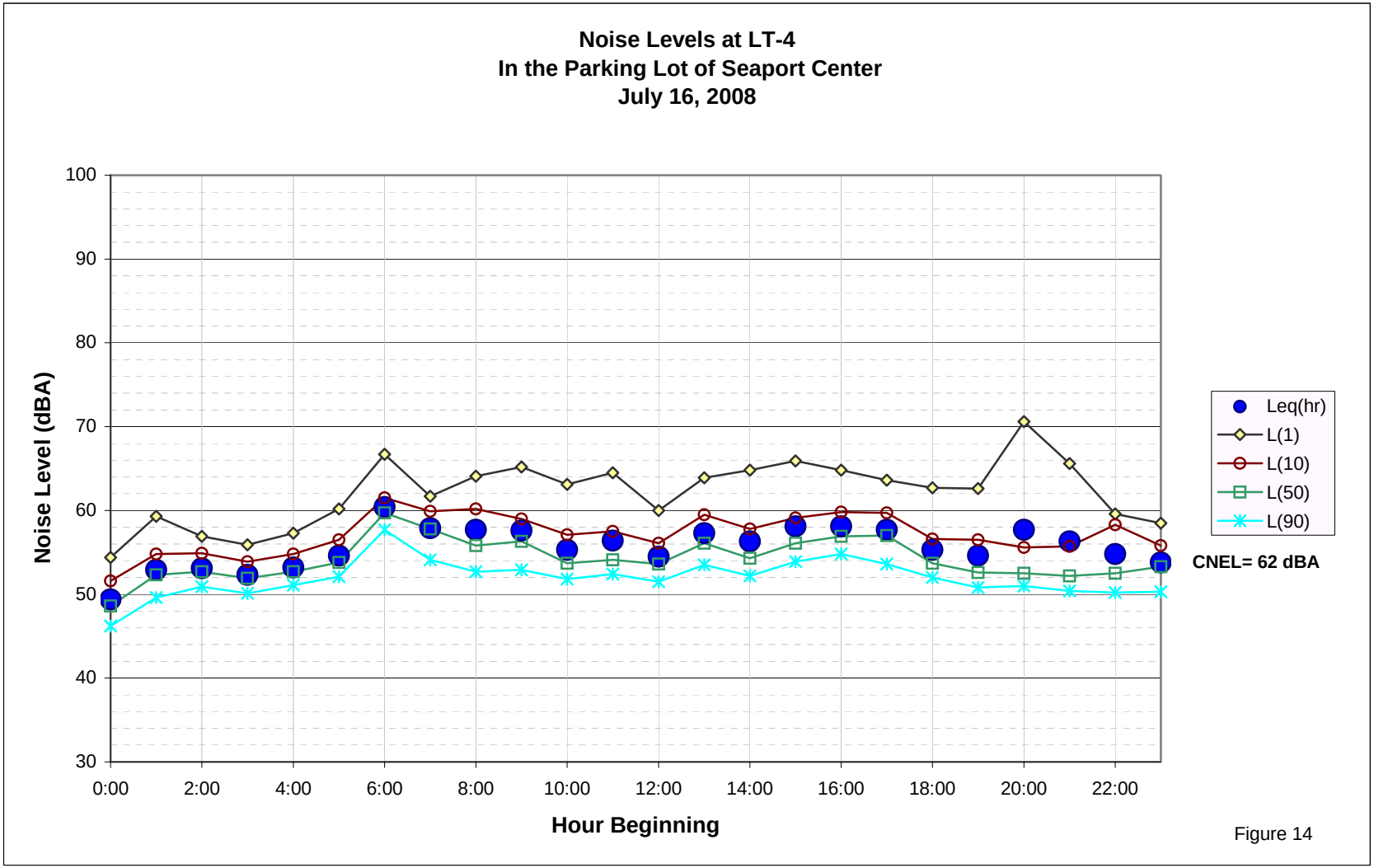

Noise Levels at LT-4
In the Parking Lot of Seaport Center
July 16, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL= 62 dBA

Figure 14

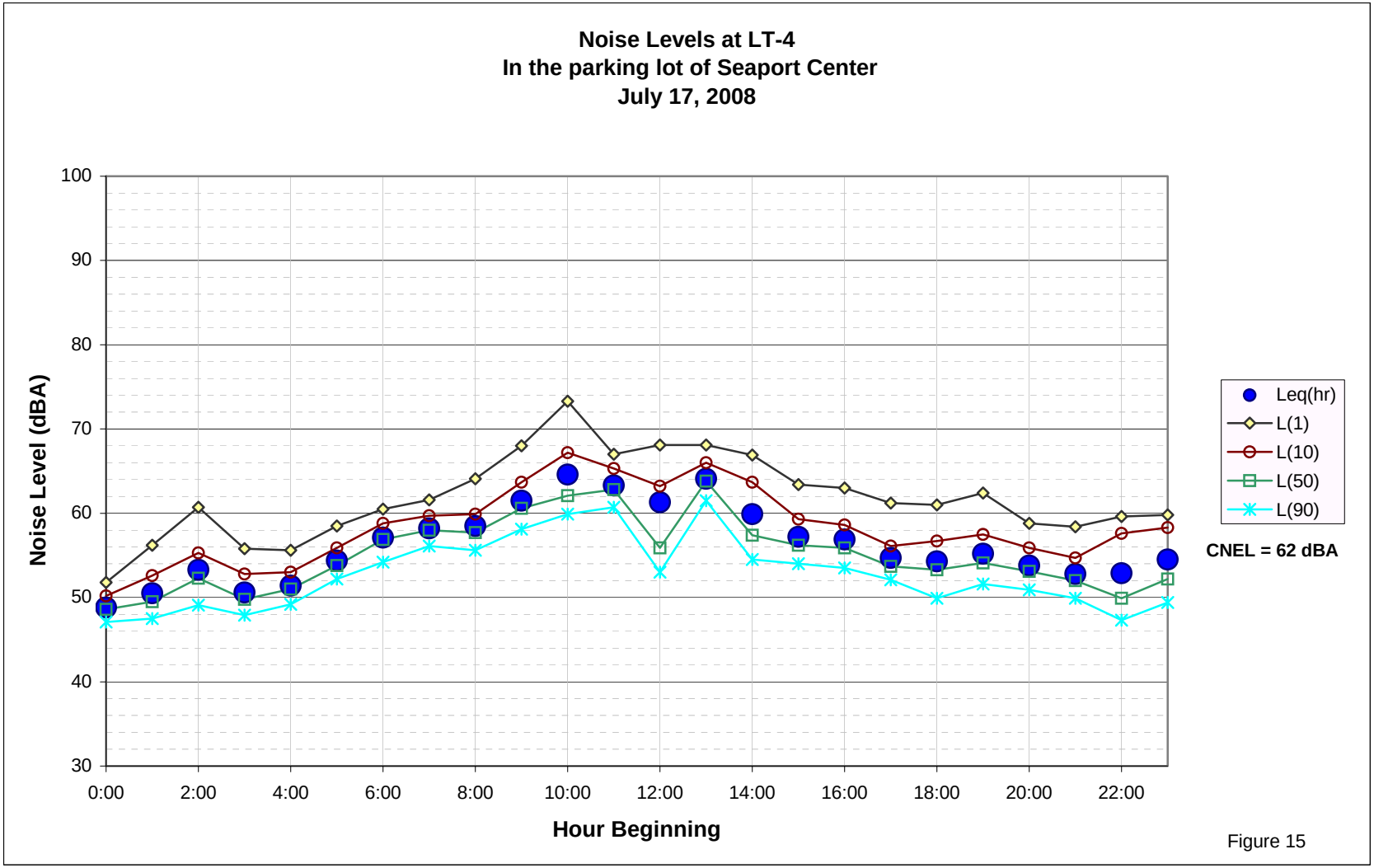

Noise Levels at LT-4
In the parking lot of Seaport Center
July 17, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 62 dBA

Figure 15

Noise Levels at LT-5
Fair Oaks Avenue between 7th Avenue and 8th Avenue across from Caltrain Station
July 16, 2008

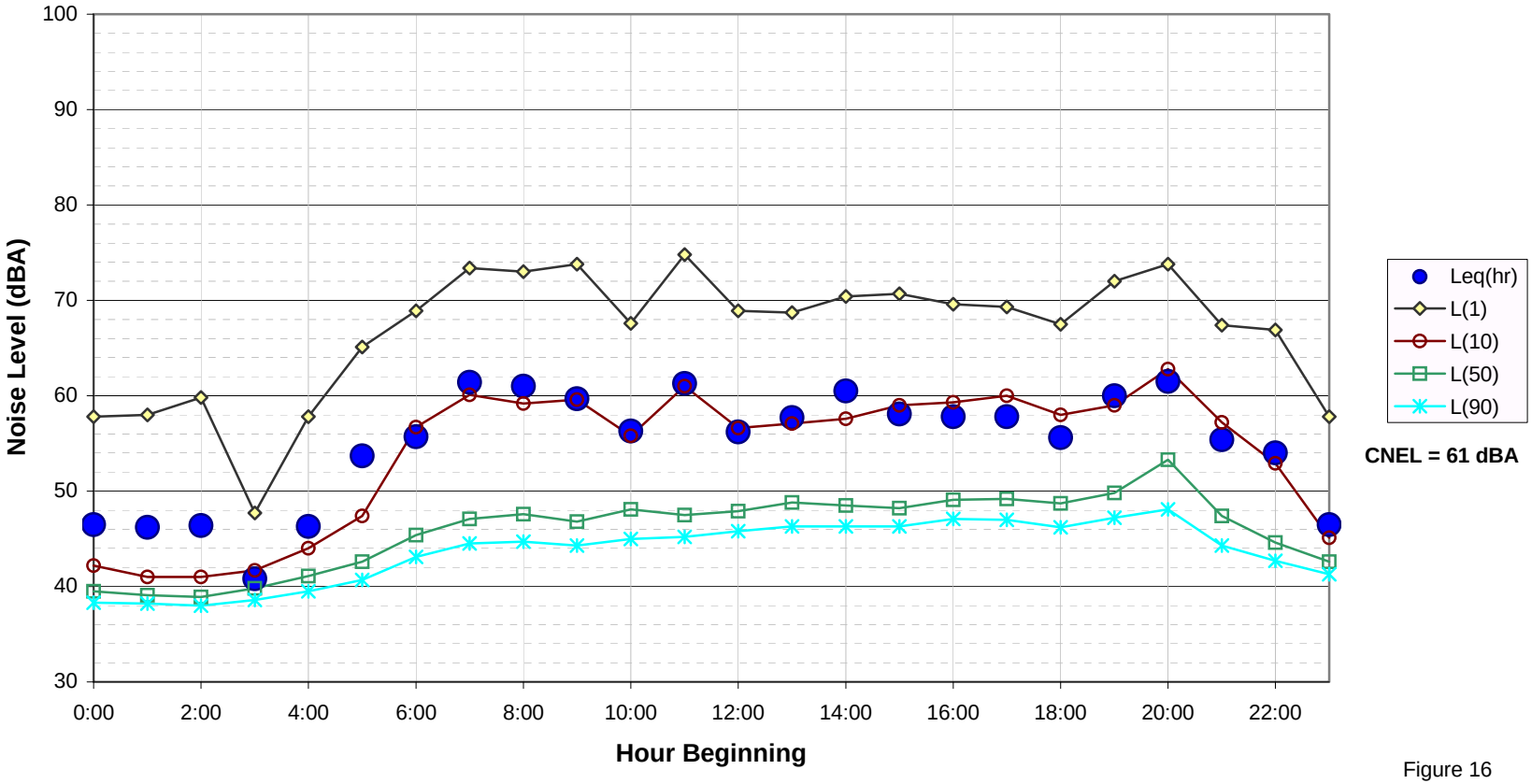
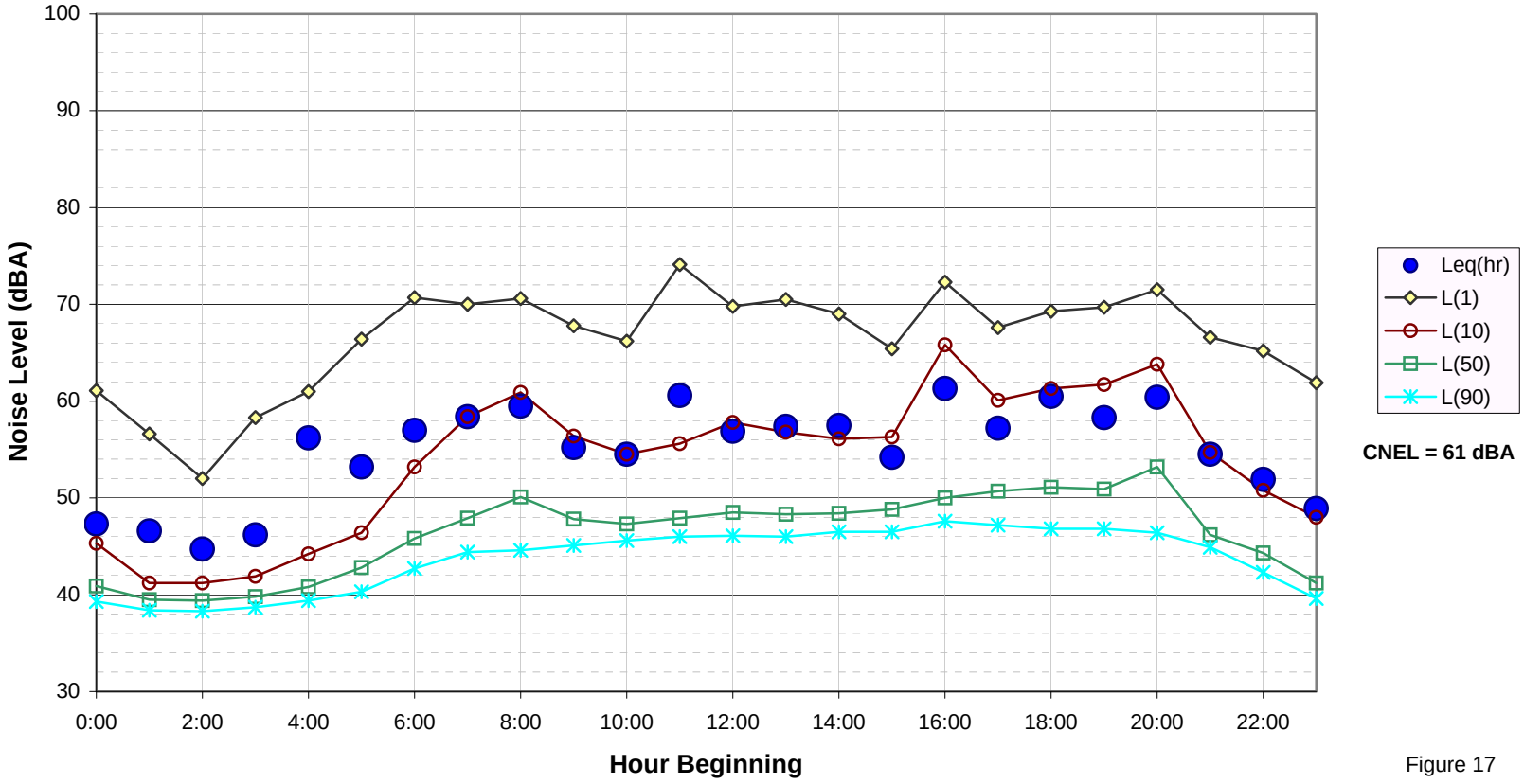


Figure 16

Noise Levels at LT-5
Fair Oaks Avenue between 7th Avenue and 8th Avenue across from Caltrain Station
July 17, 2008



CNEL = 61 dBA

Figure 17

Noise Levels at LT-6
Glendale Avenue between Amherst Avenue and 5th Avenue across from Caltrain Station
July 16, 2008

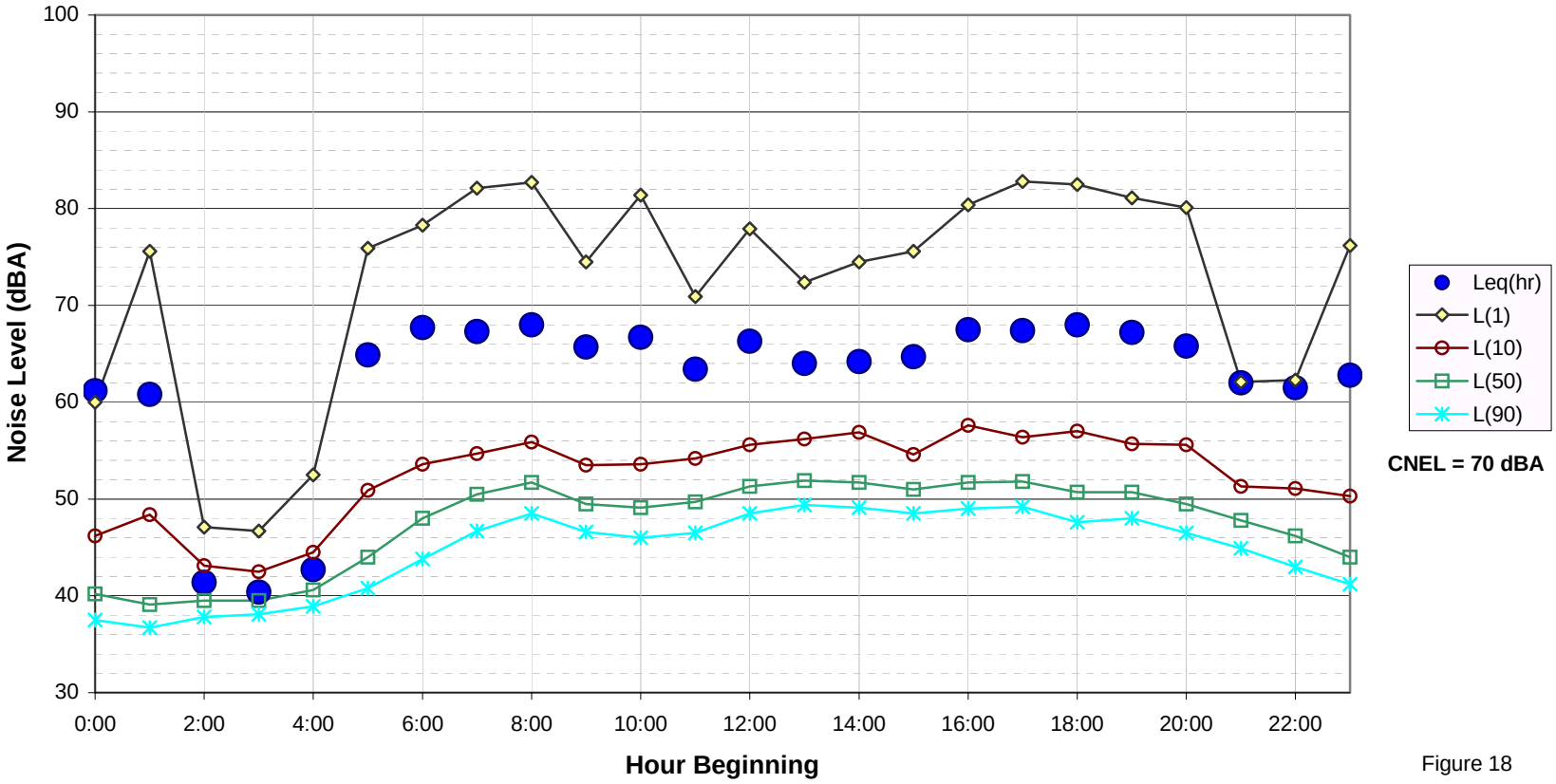
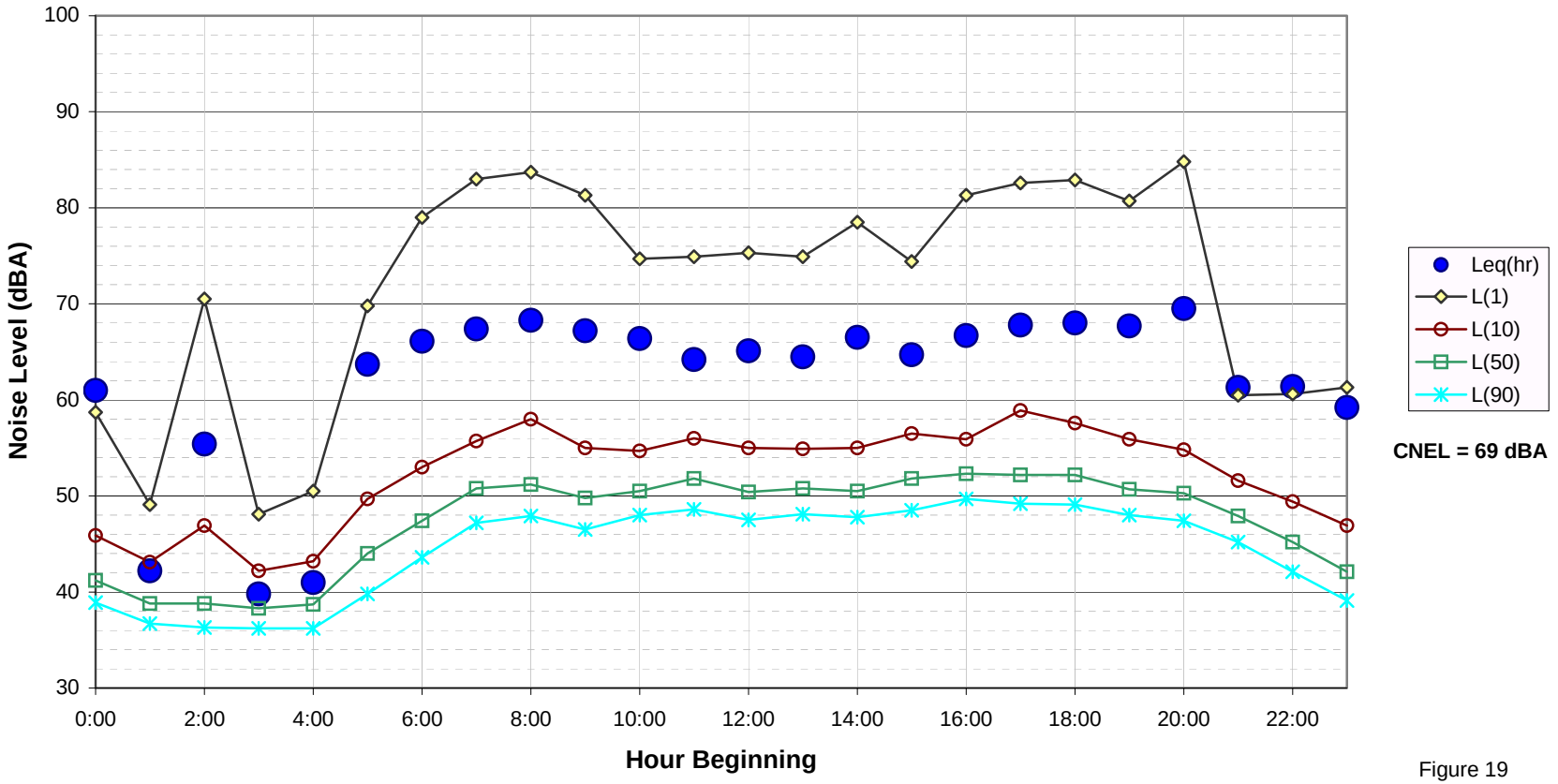


Figure 18

Noise Levels at LT-6
On Glendale Avenue between Amherst Avenue and 5th Avenue across from Caltrain Station
July 17, 2008



CNEL = 69 dBA

Figure 19

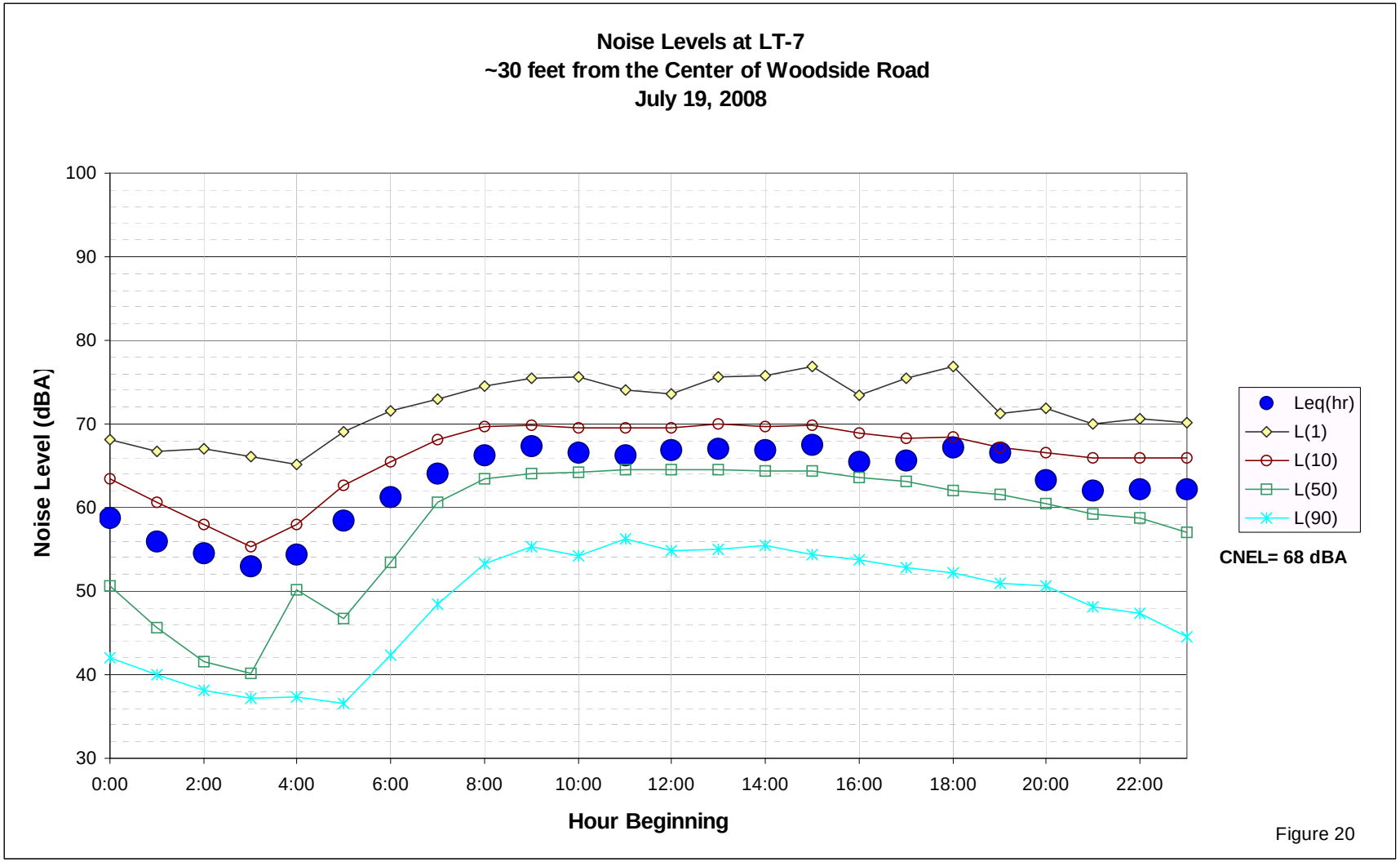
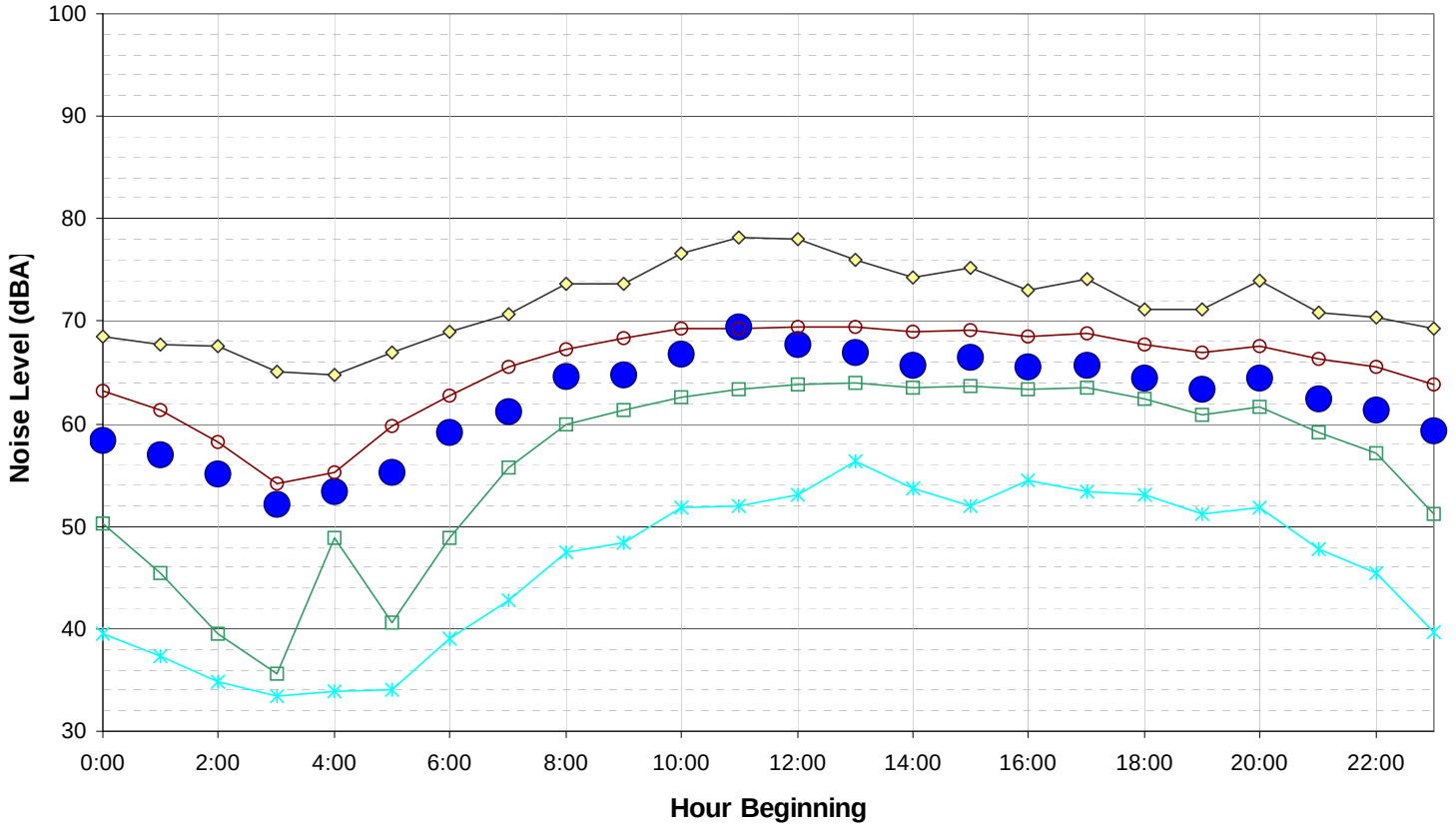

Noise Levels at LT-7
~30 feet from the Center of Woodside Road
July 19, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL= 68 dBA

Figure 20

Noise Levels at LT-7
~30 feet from the Center of Woodside Road
July 20, 2008



CNEL = 67 dBA

Figure 21

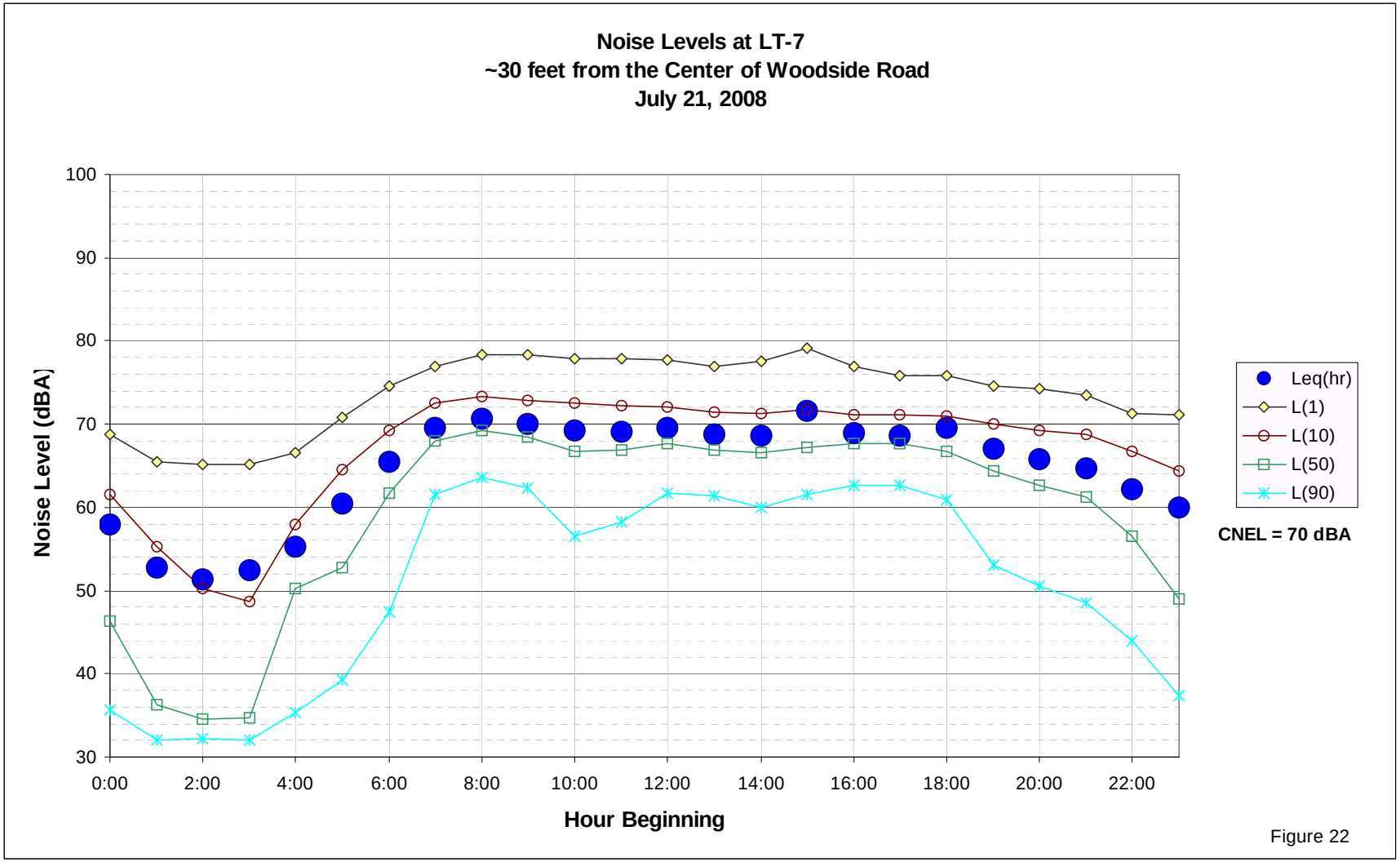

Noise Levels at LT-7
~30 feet from the Center of Woodside Road
July 21, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 70 dBA

Figure 22

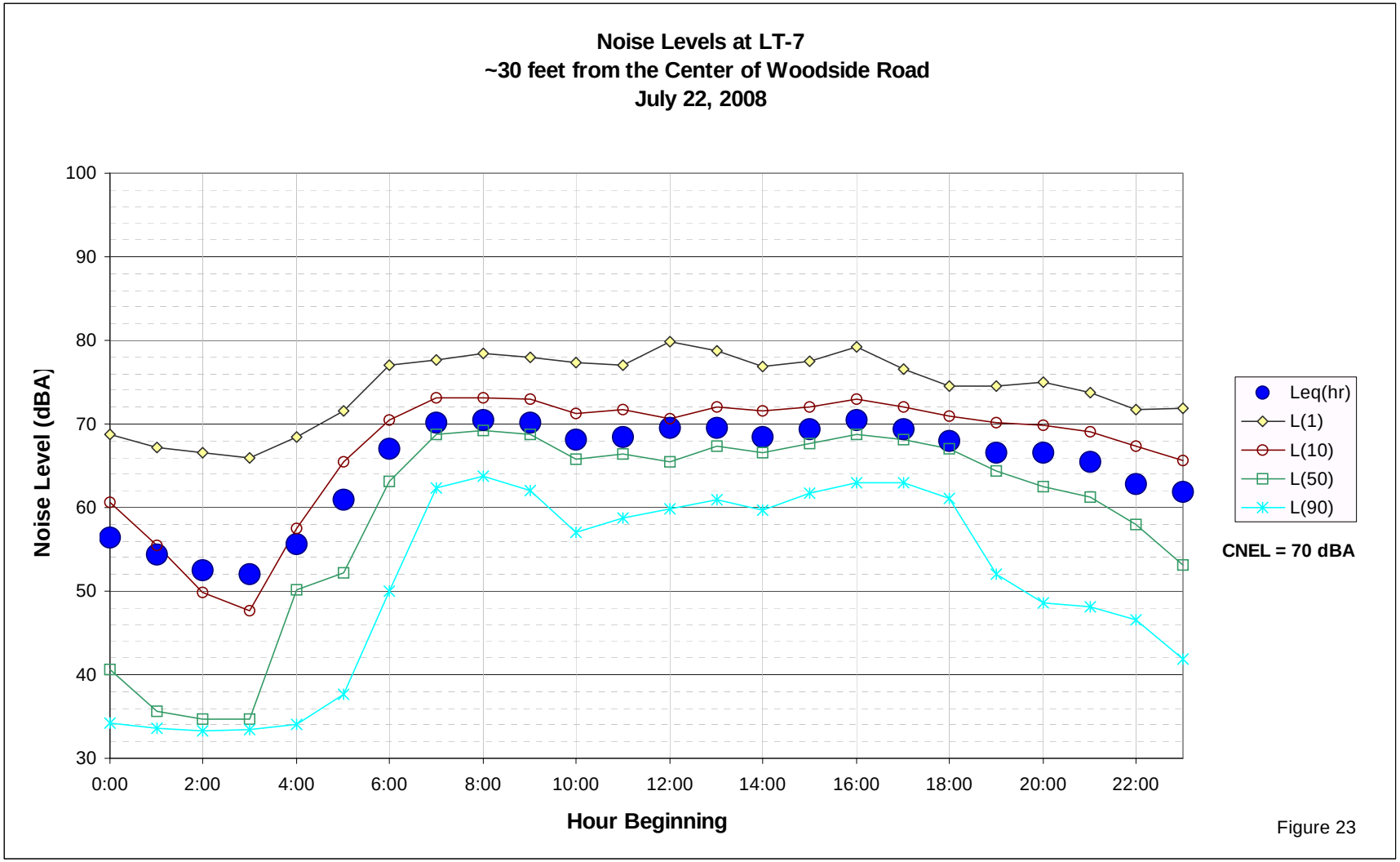

Noise Levels at LT-7
~30 feet from the Center of Woodside Road
July 22, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 70 dBA

Figure 23

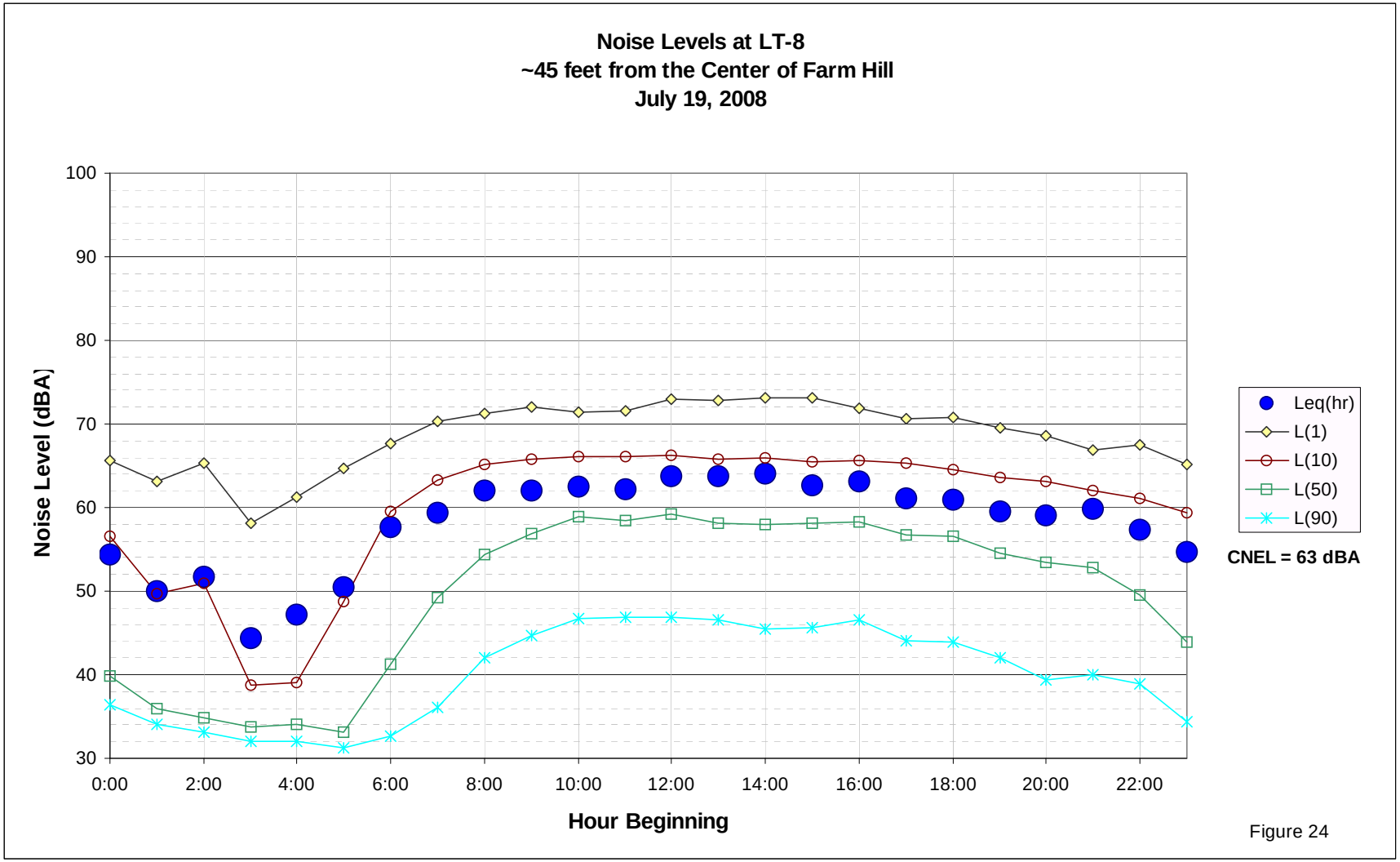

Noise Levels at LT-8
~45 feet from the Center of Farm Hill
July 19, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 63 dBA

Figure 24

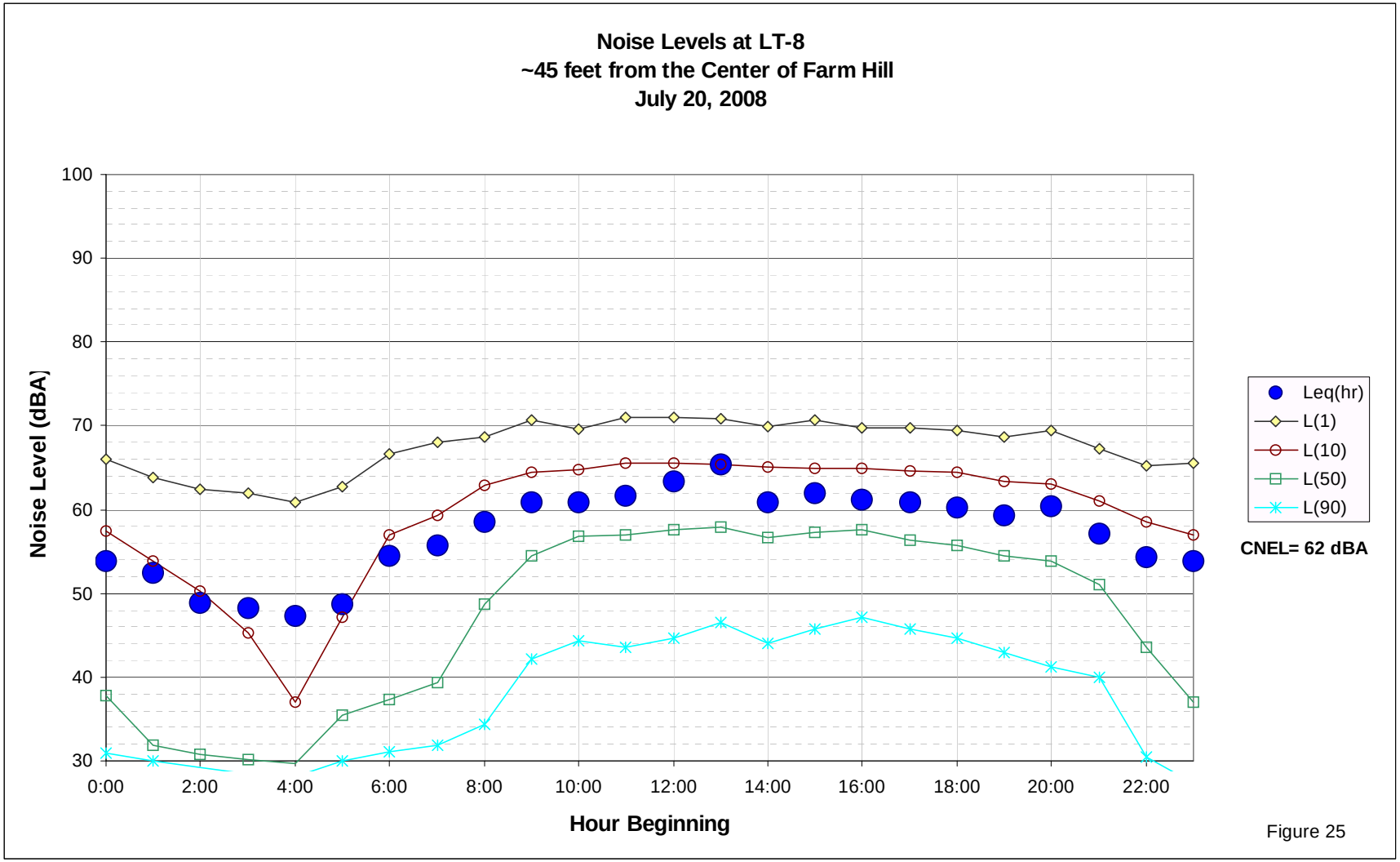

Noise Levels at LT-8
~45 feet from the Center of Farm Hill
July 20, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL= 62 dBA

Figure 25

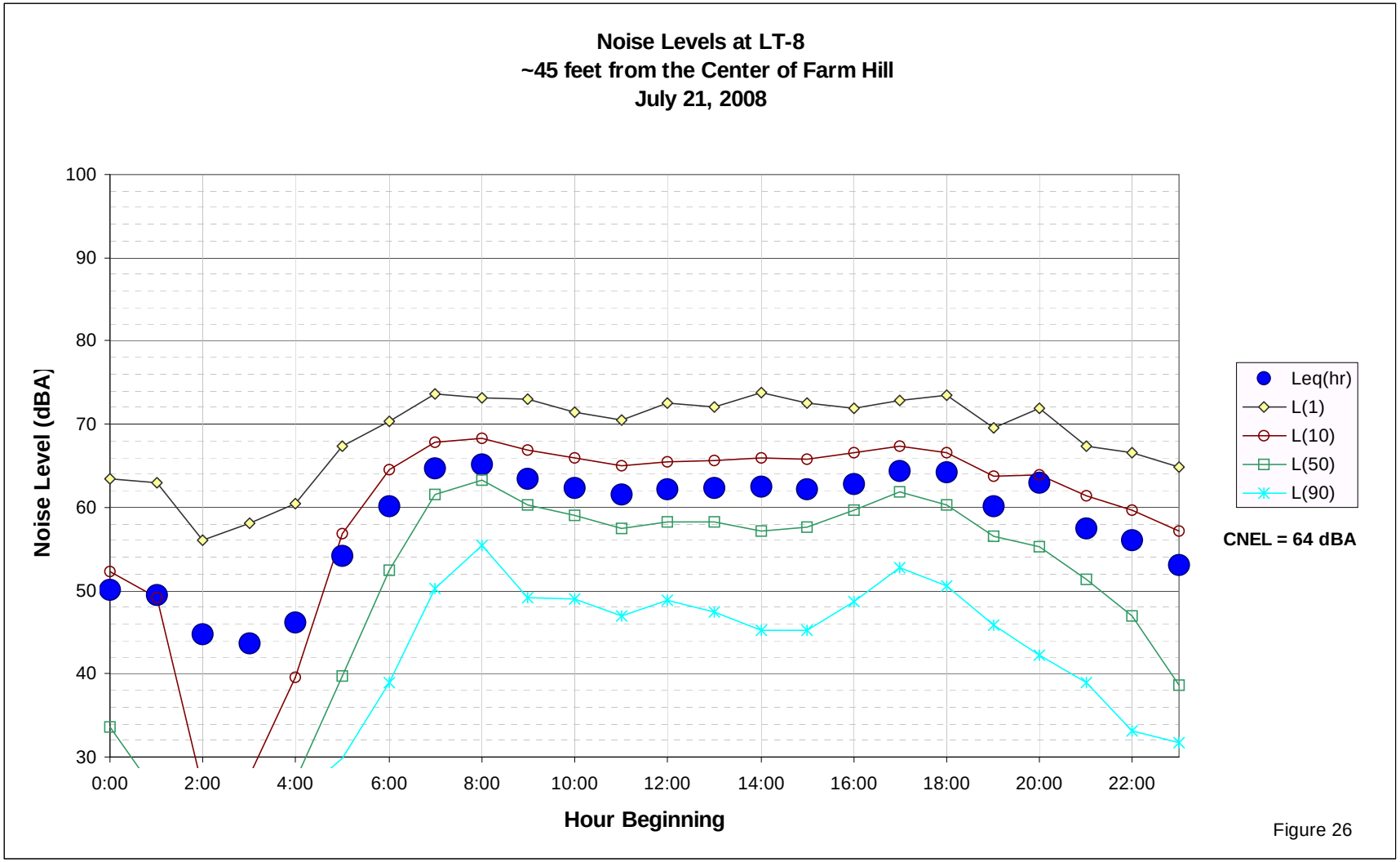

Noise Levels at LT-8
~45 feet from the Center of Farm Hill
July 21, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 64 dBA

Figure 26

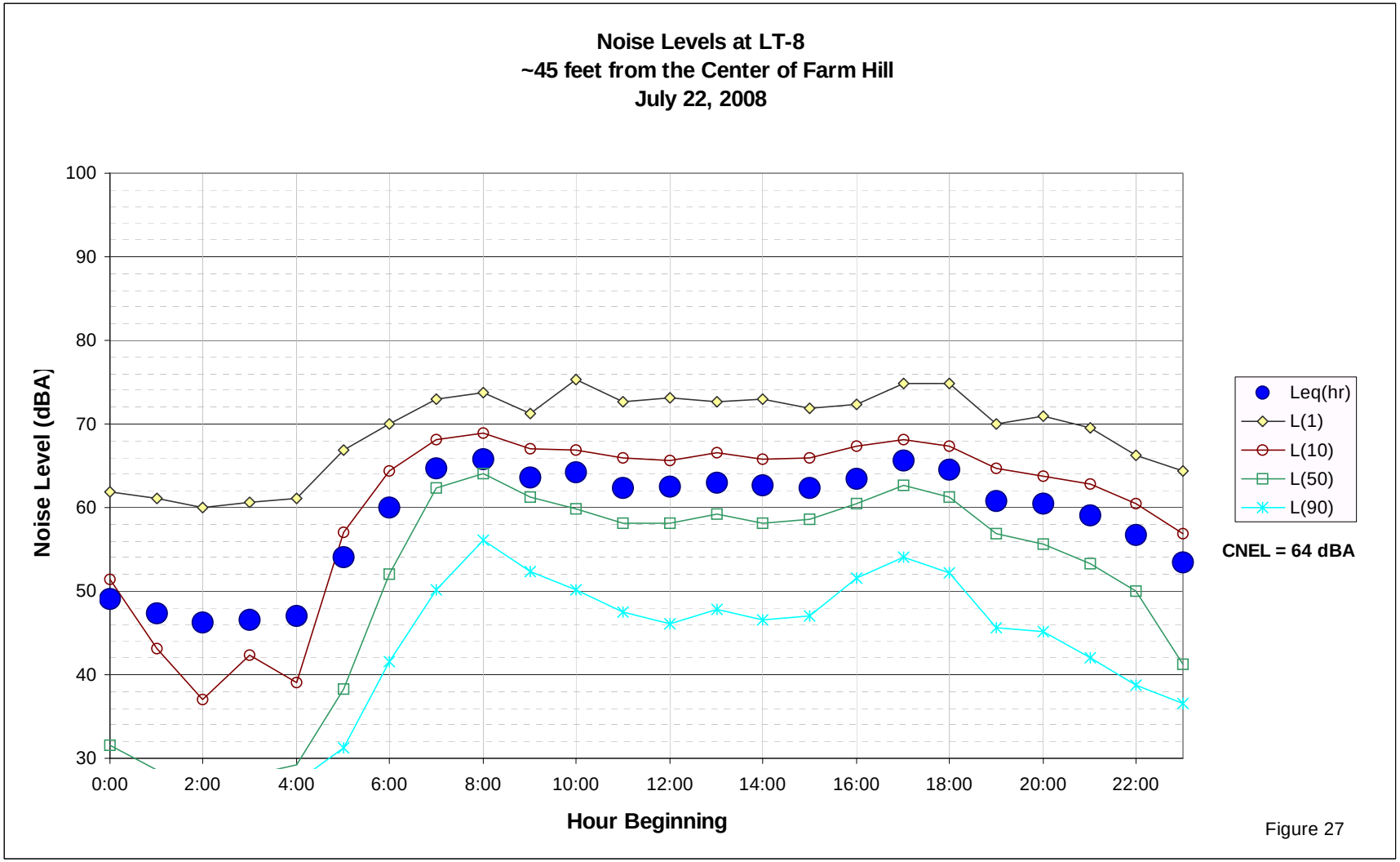

Noise Levels at LT-8
~45 feet from the Center of Farm Hill
July 22, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 64 dBA

Figure 27

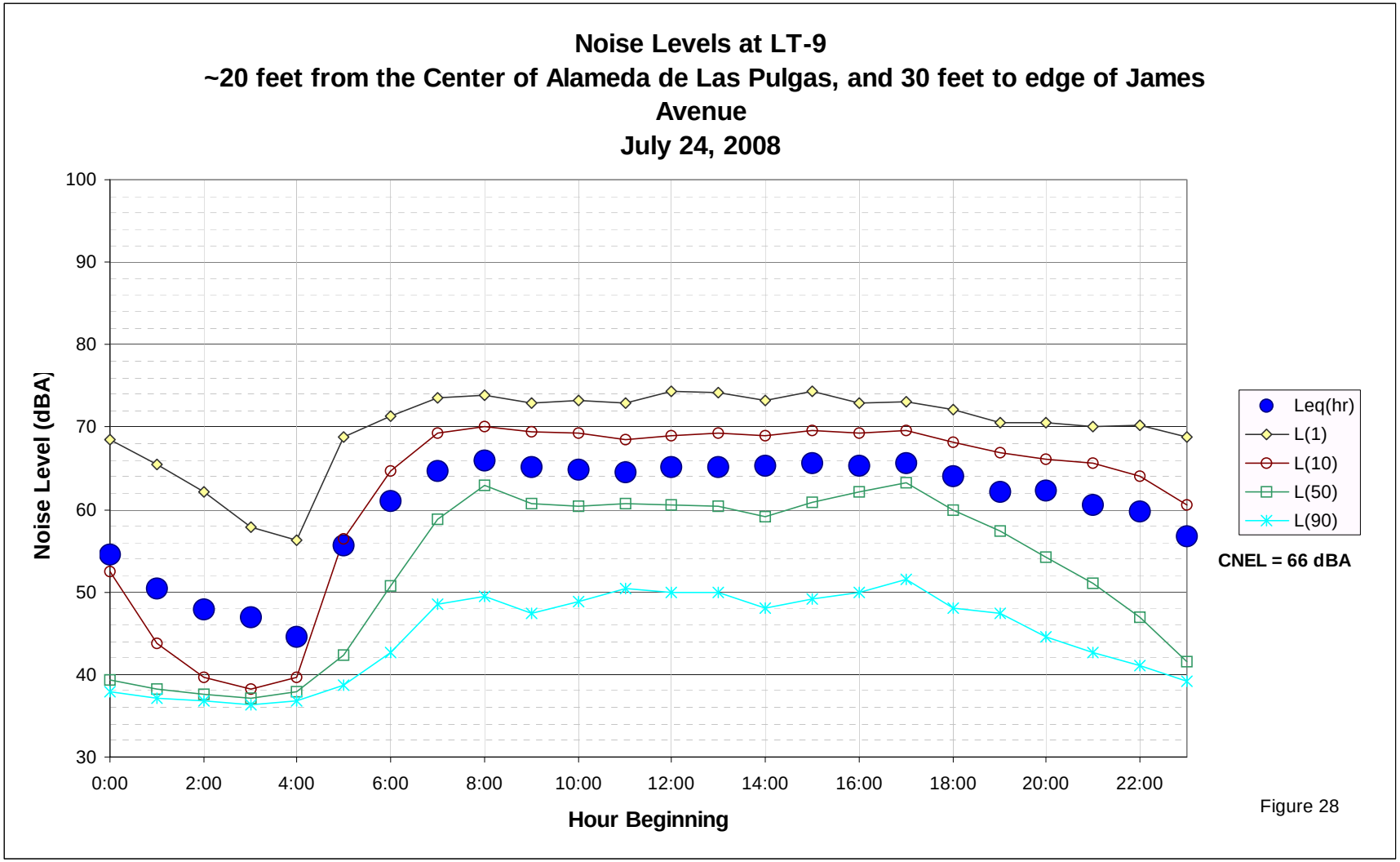

Noise Levels at LT-9
~20 feet from the Center of Alameda de Las Pulgas, and 30 feet to edge of James Avenue
July 24, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 66 dBA

Figure 28

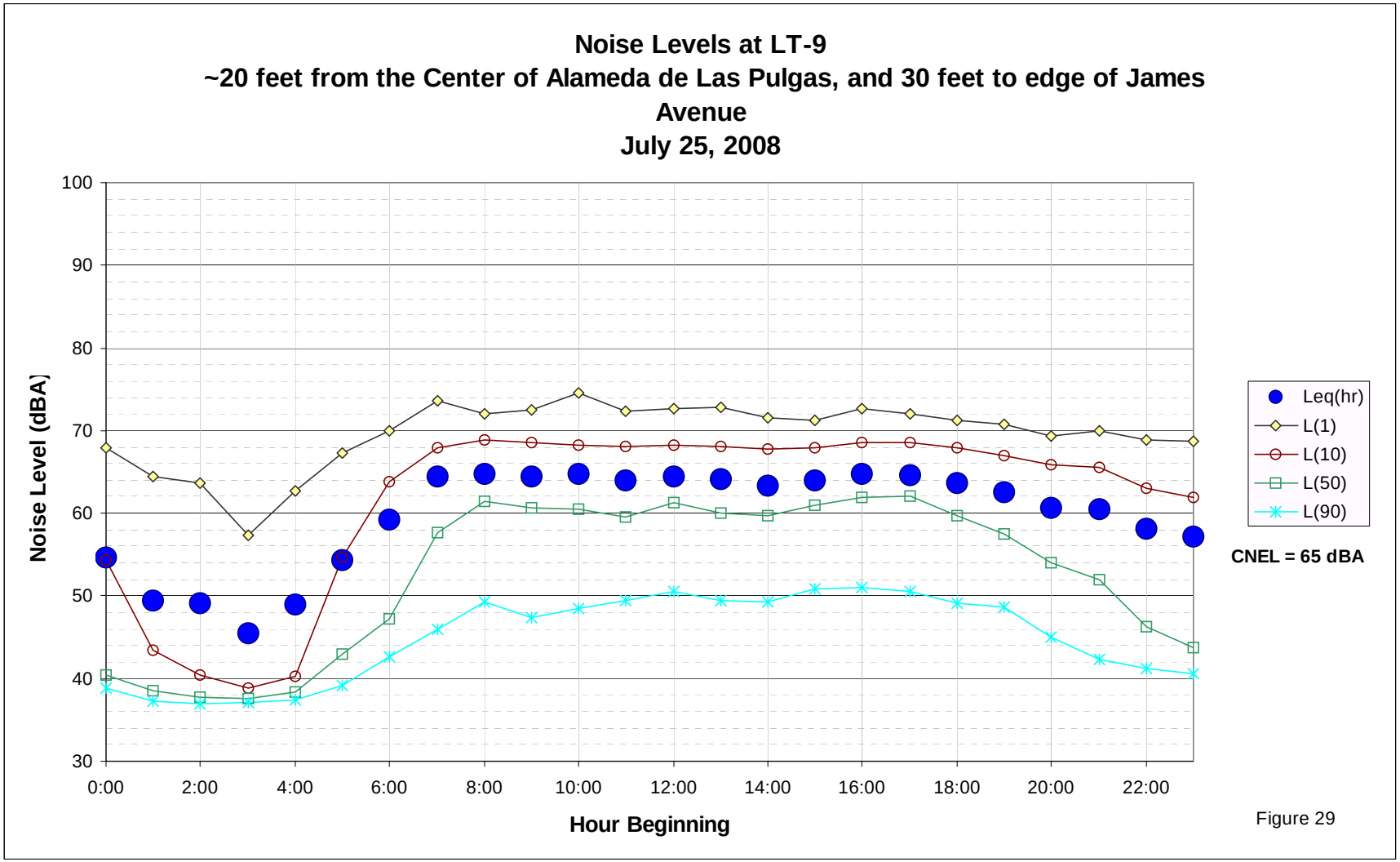

Noise Levels at LT-9
~20 feet from the Center of Alameda de Las Pulgas, and 30 feet to edge of James Avenue
July 25, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 65 dBA

Figure 29

Noise Levels at LT-9
~20 feet from the Center of Alameda de Las Pulgas, and 30 feet to edge of James Avenue
July 26, 2008

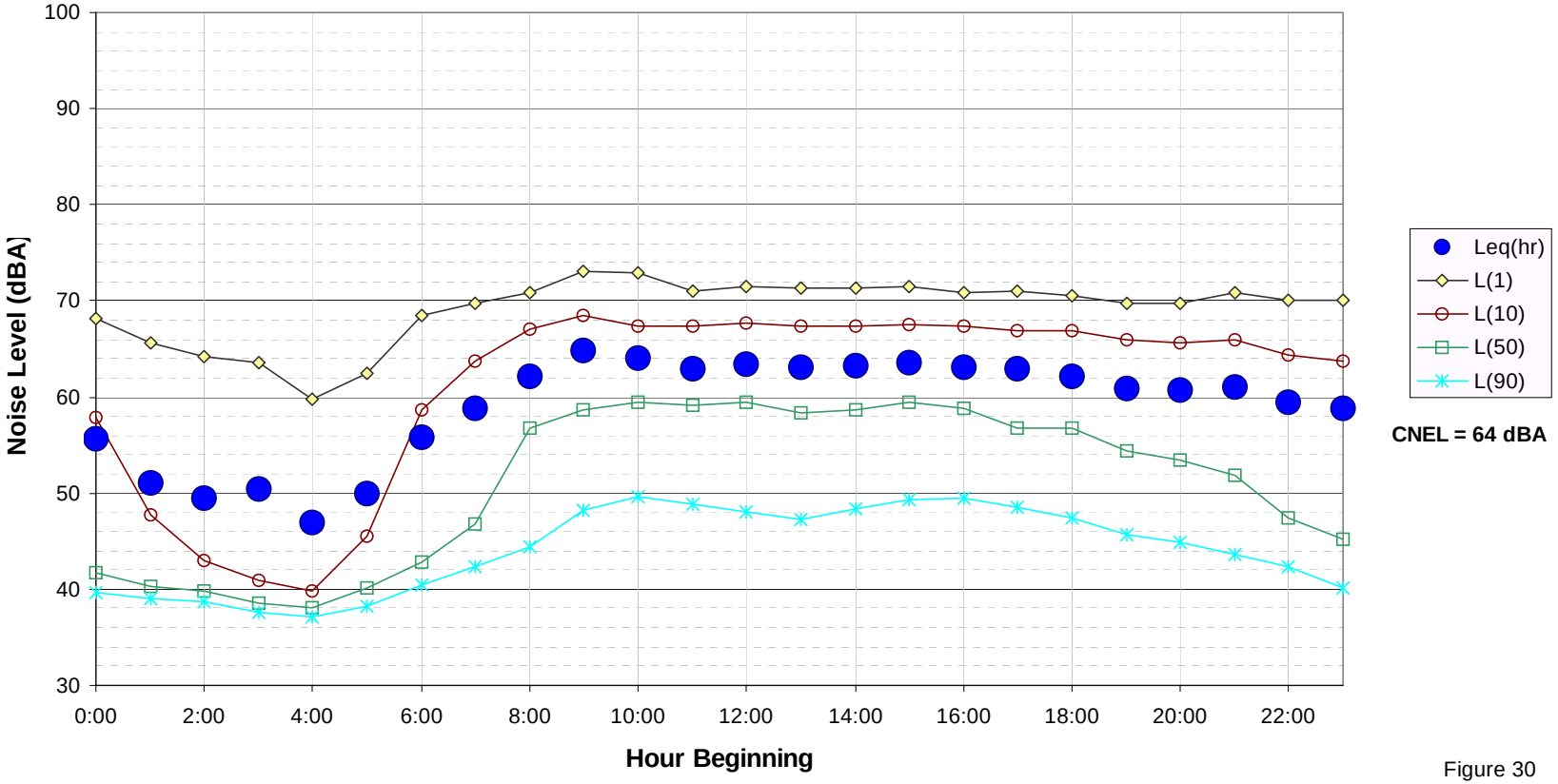


Figure 30

Noise Levels at LT-9
~20 feet from the Center of Alameda de Las Pulgas, and 30 feet to edge of James Avenue
July 27, 2008

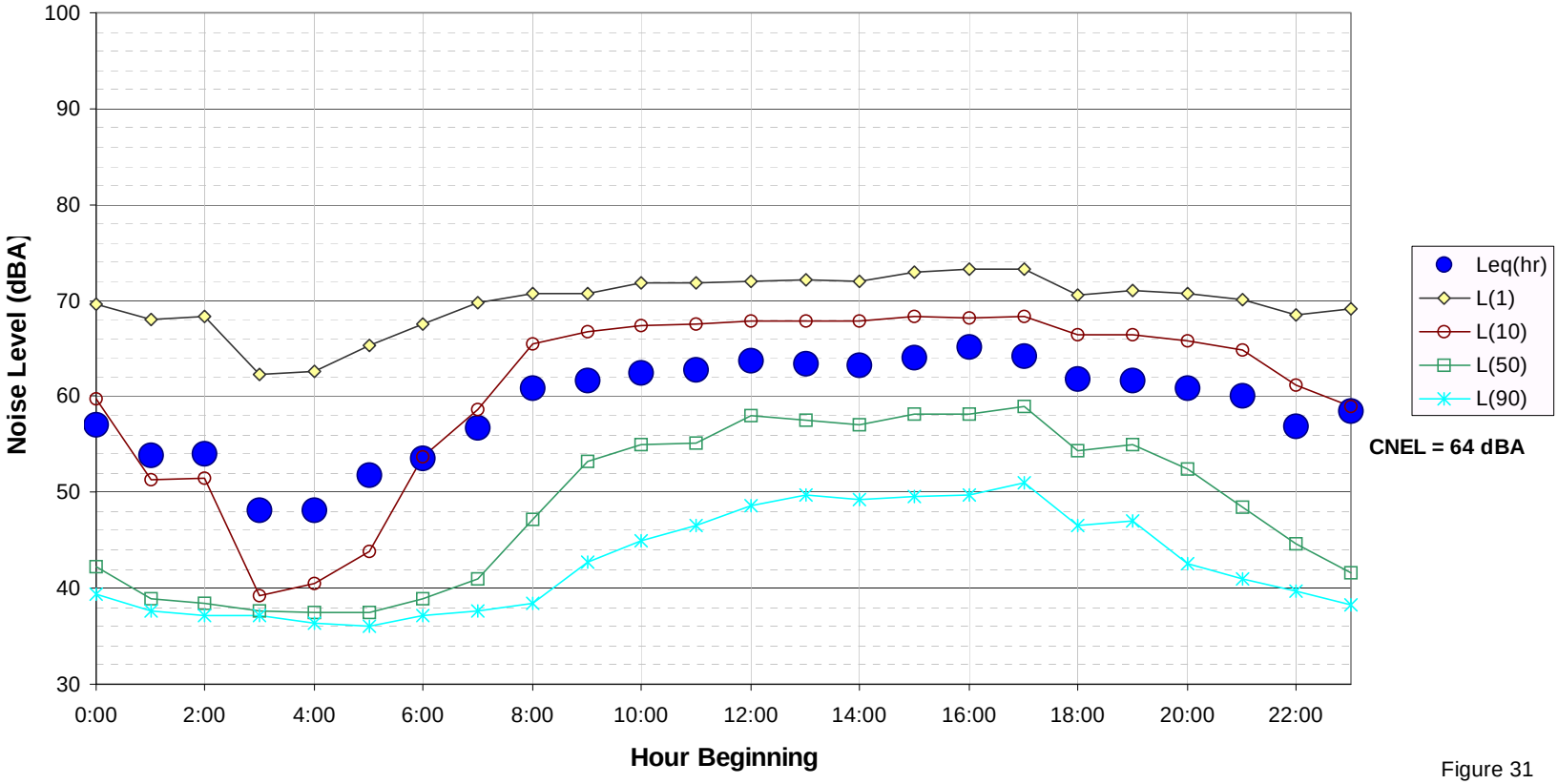


Figure 31

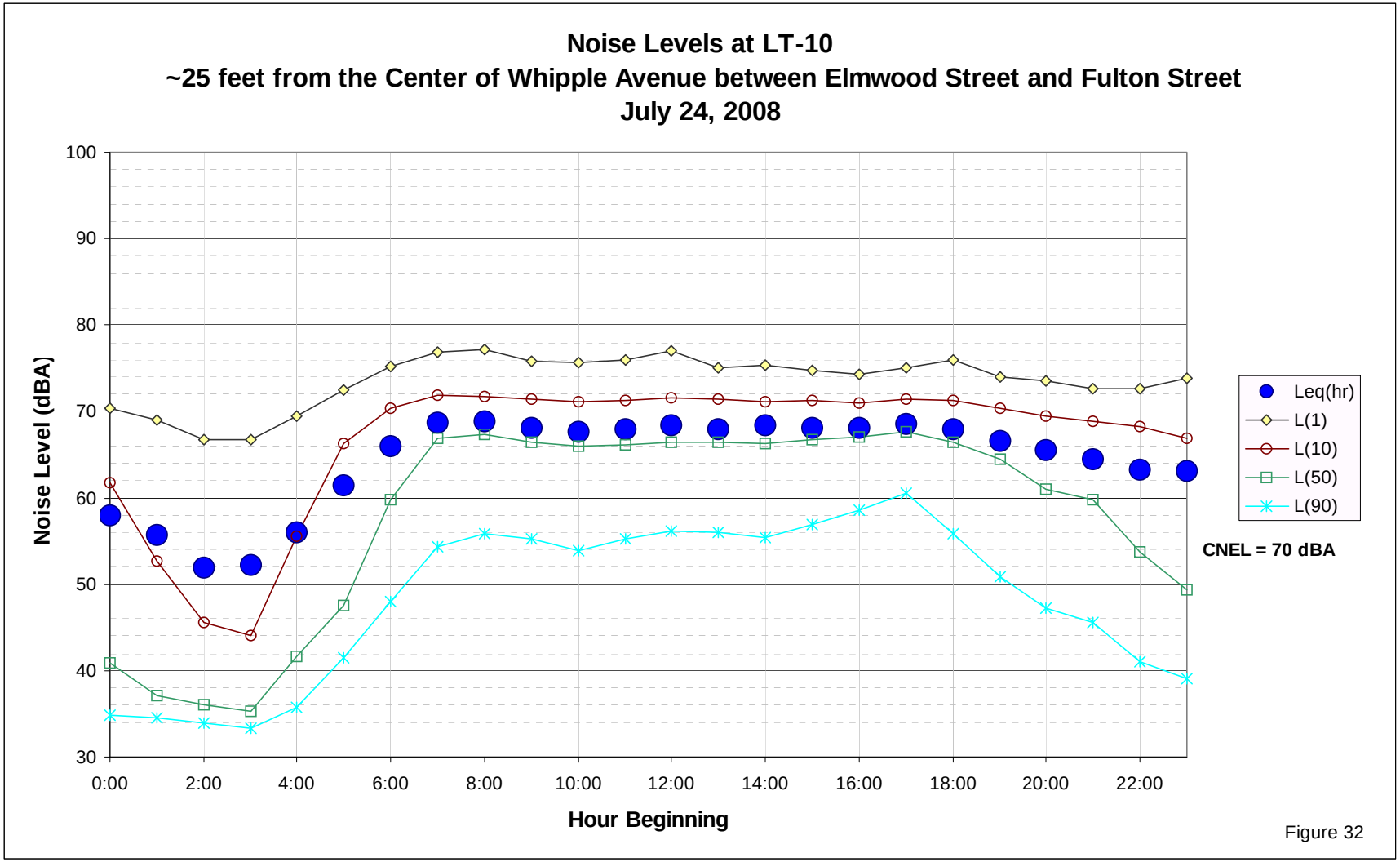

Noise Levels at LT-10
~25 feet from the Center of Whipple Avenue between Elmwood Street and Fulton Street
July 24, 2008
Noise Level (dBA)
100
90
80
70
60
50
40
30
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Hour Beginning
Leq(hr)
L(1)
L(10)
L(50)
L(90)
CNEL = 70 dBA

Figure 32

Noise Levels at LT-10
~25 feet from the Center of Whipple Avenue between Elmwood Street and Fulton Street
July 25, 2008

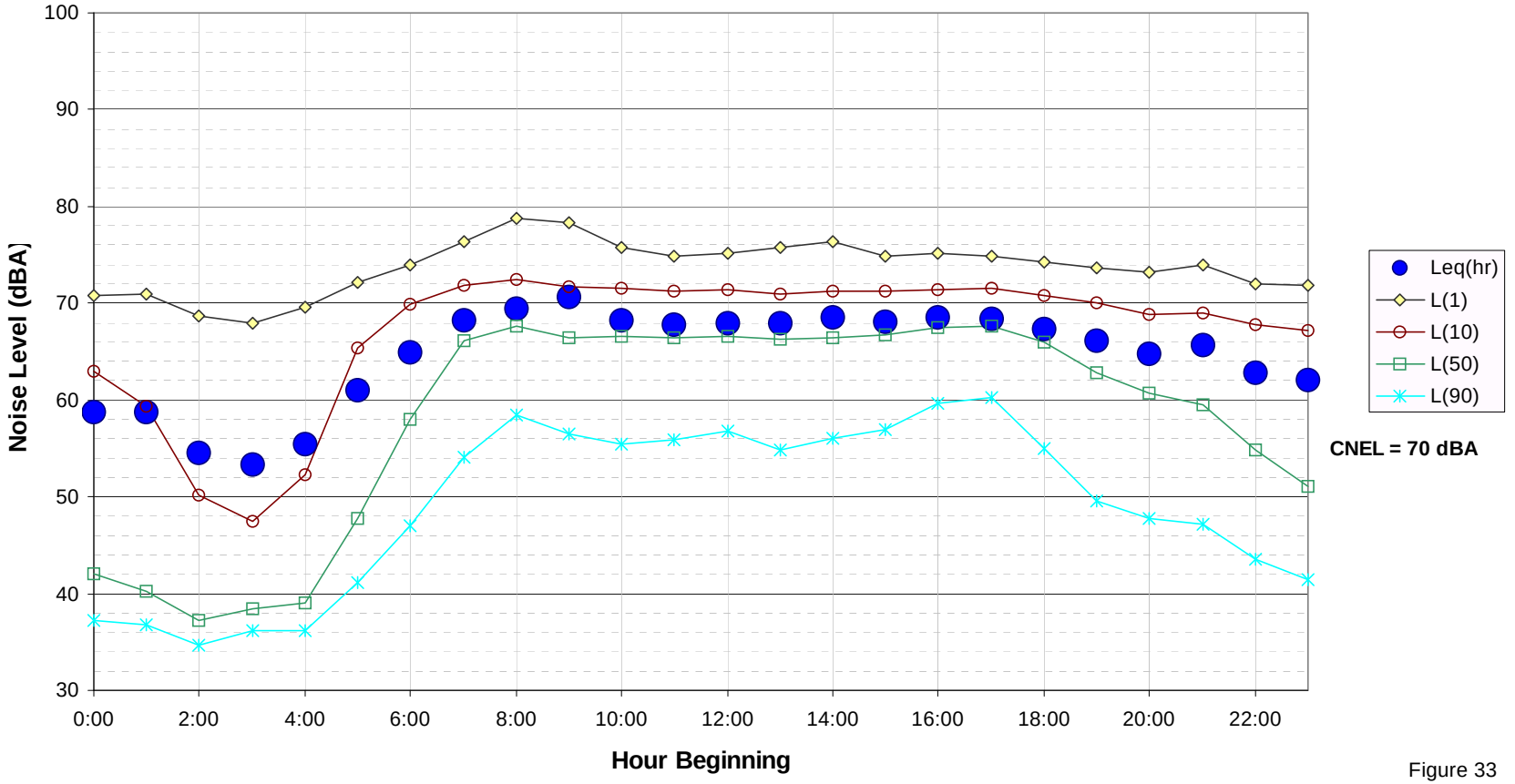


Figure 33

Noise Levels at LT-10
~25 feet from the Center of Whipple Avenue between Elmwood Street and Fulton Street
July 26, 2008

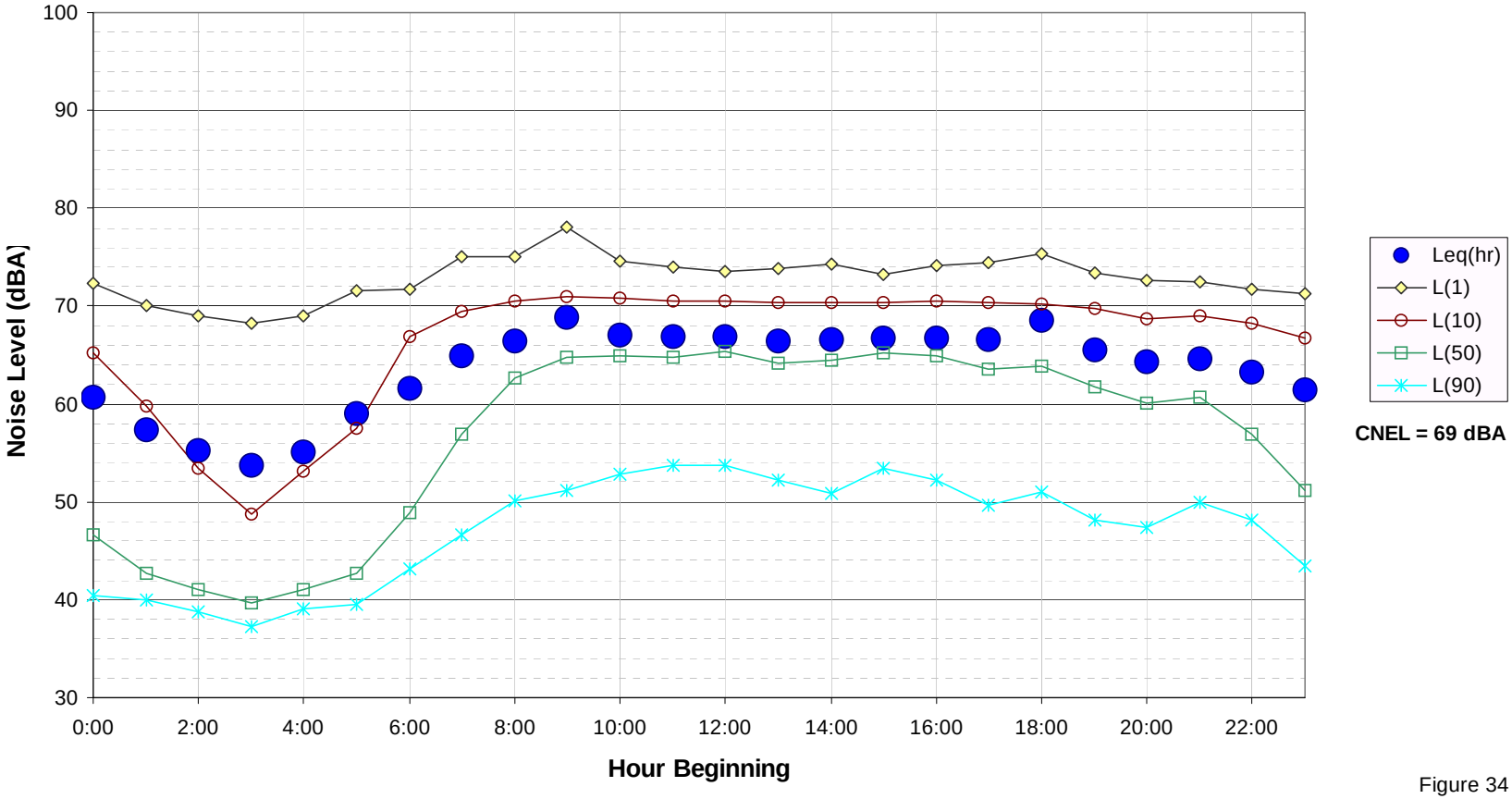


Figure 34

Noise Levels at LT-10
~25 feet from the Center of Whipple Avenue between Elmwood Street and Fulton Street
July 27, 2008

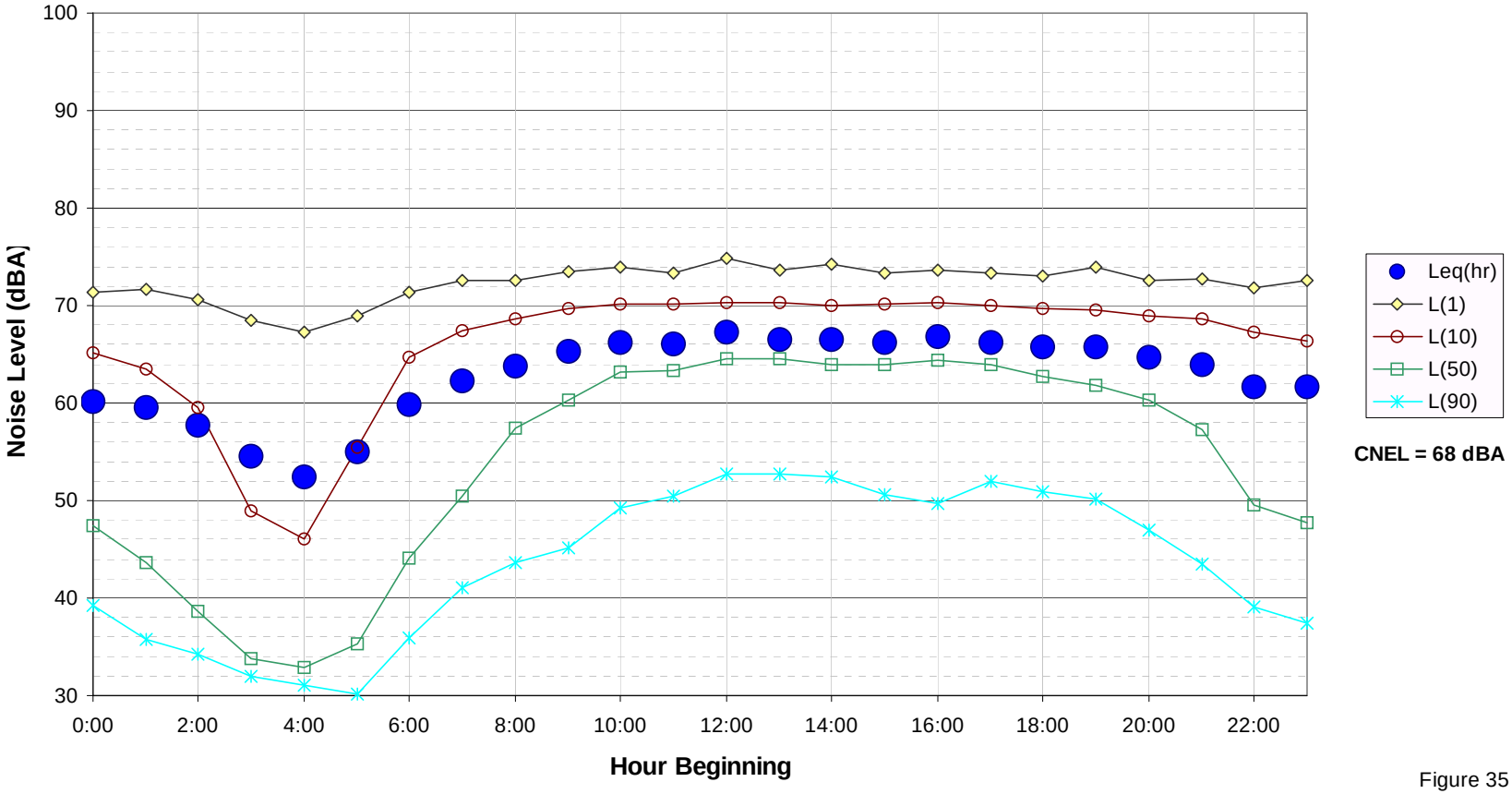


Figure 35

Noise Levels at LT-11
~25 feet from the Center of El Camino Real South of Woodside Boulevard
July 24, 2008

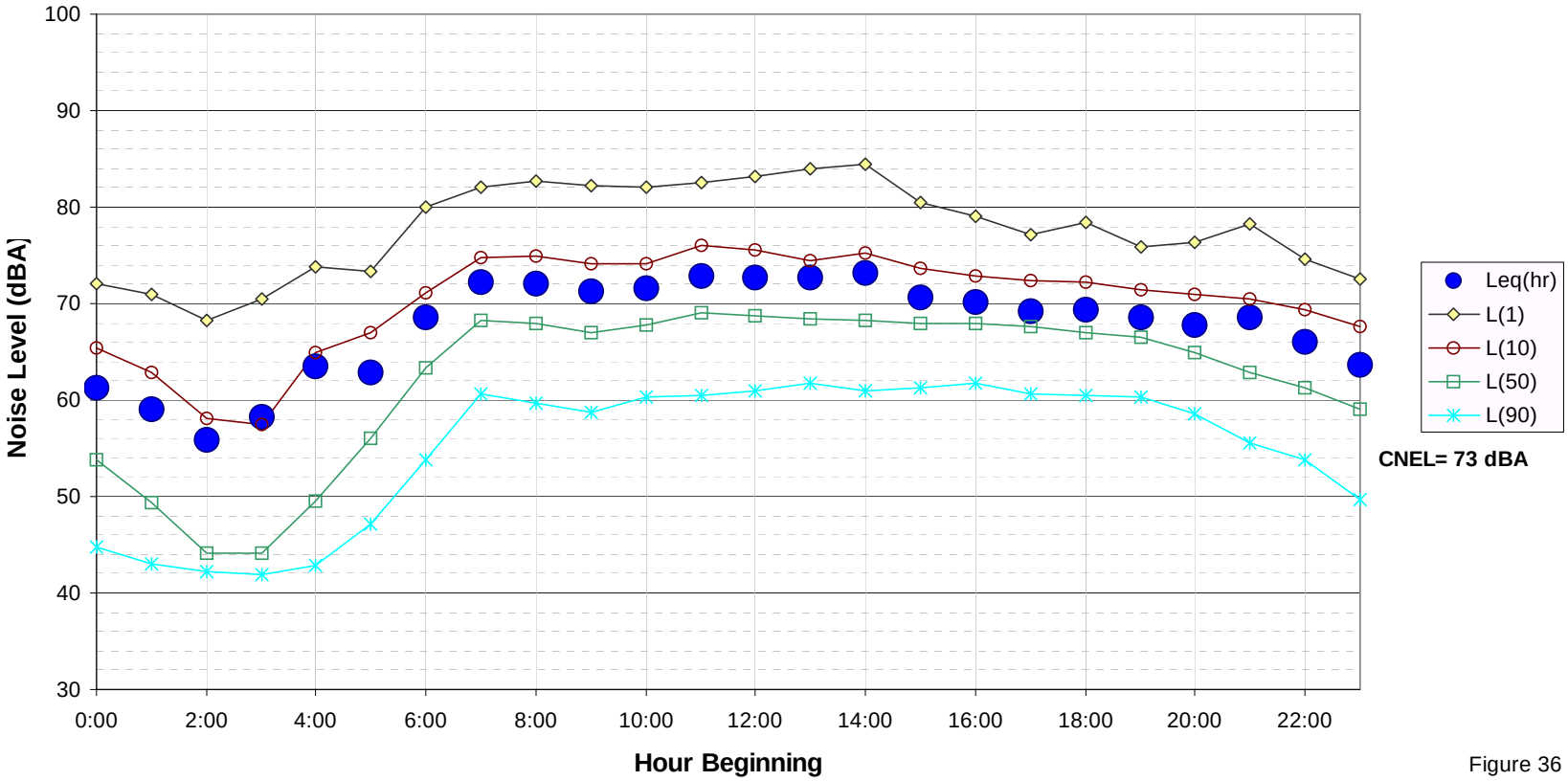


Figure 36

Noise Levels at LT-11
~25 feet from the Center of El Camino Real South of Woodside Boulevard
July 25, 2008

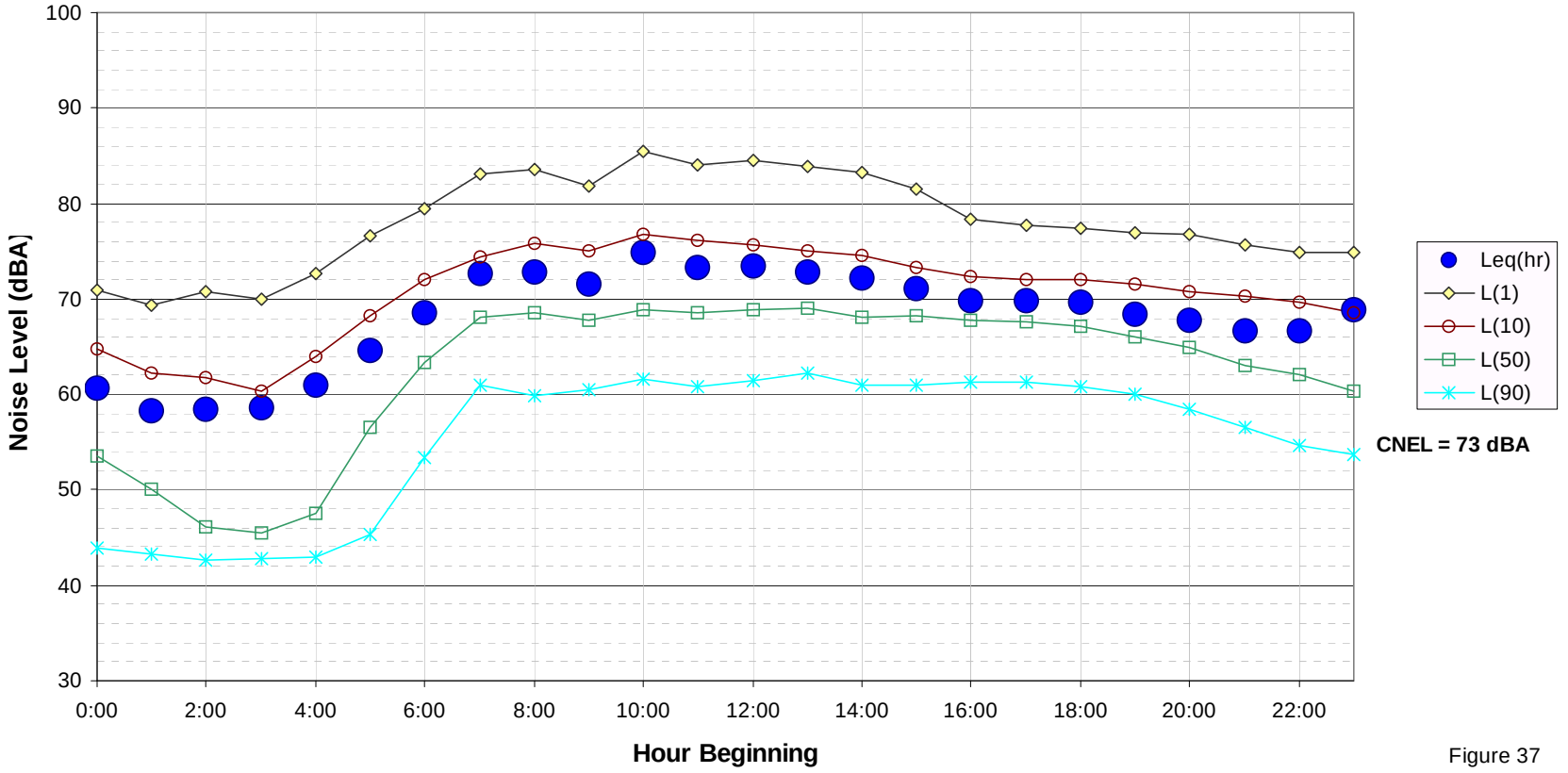


Figure 37

Noise Levels at LT-11
~25 feet from the Center of El Camino Real South of Woodside Boulevard
July 26, 2008

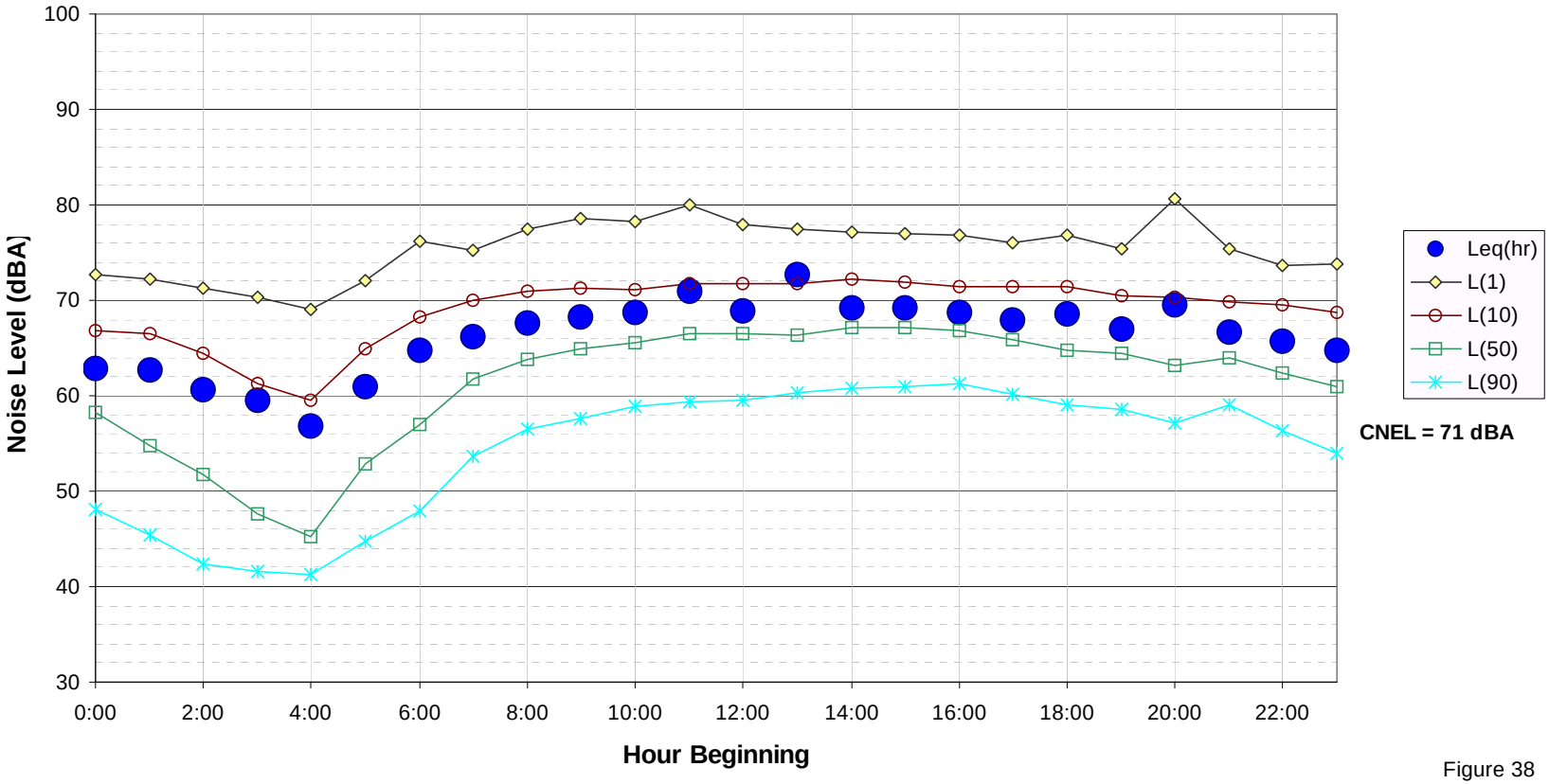


Figure 38

Noise Levels at LT-11
~25 feet from the Center of El Camino Real South of Woodside Boulevard
July 27, 2008

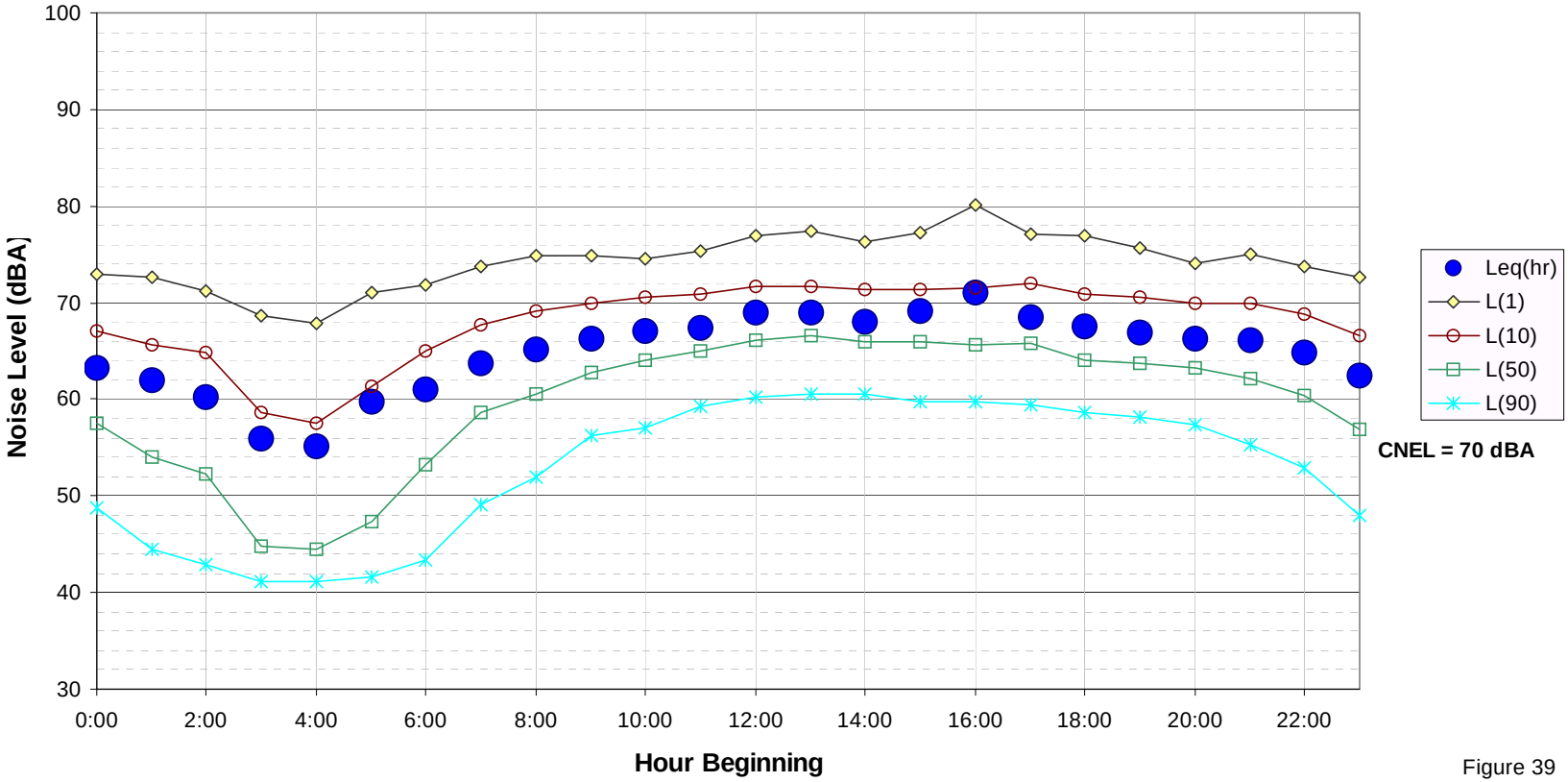


Figure 39