RUSSELL ACOUSTICS, LLC
Consulting Engineers in Sound and Vibration

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8 July 2021

Mr. Lawrence R. Harder
ER/UDC North Brunswick, LLC
250 Miron Drive
Southlake, TX 76092

Re: QuickChek – North Brunswick, NJ
Operational Sound Levels

Dear Mr. Harder:

Russell Acoustics, LLC was retained to study the proposed QuickChek on Route 130 to assess the expected sounds from the operation and, if needed, recommend mitigation measures beyond the initially proposed berm and sound barrier combination. We were later asked to review an alternative plan with a different barrier location. Figure 1 shows the original site plan and, in particular, the residential development to the west of your site.

Summary

- Measurements of existing sounds on the west side of the site show sound levels exceeding the State nighttime noise standard of 50 dBA 60 to 70 percent of the time, depending on location. Your site is not responsible for these sounds.
- The addition of a berm and six feet high sound barrier on top will keep the maximum sounds from truck operations under the State sound level limits at their times of operation.
- An alternative configuration of a barrier-only design to reduce disturbance of the existing trees provides similar sound level reductions.
- The addition of the berm and sound wall at the rear of the site reduces sounds from Route 130 traffic 6 to 8 dBA at the residences behind the site.

Ambient Sound Measurements

We set up two environmental sound monitoring systems along the western side of the property to assess the sounds going over to the residential use to the west. The numbered pointers on Figure 2 show the locations and the numbers correspond to the numbers on the three subsequent sound level graphs. Figure 3 explains the various parts of the actual graphs from the ambient testing, shown on Figures 4 and 5.

The monitors operated around the clock from the morning of Thursday, 20 May through Saturday, 22 May 2021, a total of 72 hours at each location. These are the existing sound levels. The green line on each graph shows the maximum sound levels the proposed operation is allowed to make at the receiving residential properties from its regulated activities. Note that the ambient sound levels do not count against you. You are not responsible for the ambient sounds.

The instruments used for the long-term sound measurements are Larson-Davis Model 703 and 705+ digital time-history sound level meters equipped with instrumentation microphones and windscreens. They meet ANSI requirements for Type 2 sound level meters. They measure and store the overall A-weighted sound pressure level ("dBA"), at programmed intervals, for programmed measurement times. Each instrument has an internal clock. These were all set and synchronized using a common digital clock, which was set using time from a GPS receiver.

Each instrument was calibrated prior to the test, and the calibration checked after the tests, with a Bruel & Kjaer Type 4230 sound level calibrator. The calibrator's own calibration is done annually and is traceable to the National Institute of Standards and Technology (NIST), following good acoustical practice. Sound levels in this report are expressed in terms of decibels relative to the ANSI-preferred reference pressure of 20 uPa. The instrument detectors were set for "slow" response.

The A-weighted sound pressure level is a measurement method that is modeled after the frequency response of the human ear. Measurements of sound using this frequency weighting correlate very well with how "loud" sounds are. It is probably the single most commonly used method for measuring sound on a worldwide basis. Within the U.S. five major Federal agencies - FAA, DOT, DOL (OSHA), HUD, and DOD - use it. The State of New Jersey noise regulation (N.J.A.C. 7:29) uses dBA measurements.

As the graphs illustrate the existing sound levels frequently exceed the maximum sound you are allowed to emit. The State Regulation limits the maximum level, not the average.

Summary of Ambient Sound Measurements

Location	**Lmin**	**L90**	**Leq**	**L10**	**Lmax**	**>50 dBA**
1	37.7	47	54.6	57	82.4	60.9%
2	38	47	55.6	58	81.3	70.5%

Where

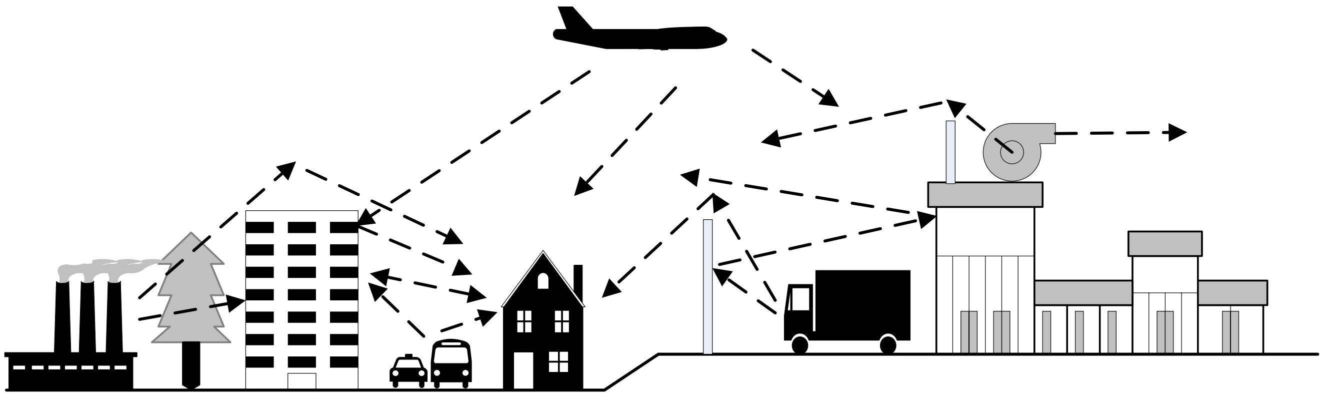
Lmin is the lowest sound level encountered for the entire study;
L90 is the sound level exceeded 90% of the time;
Leq is the energy-averaged sound level during the study;
L10 is the sound level exceeded 10% of the time;
Lmax is the highest sound level encountered over the entire study; and
>50 dBA is the % of time the sound levels were above 50 dBA.

The green line on Figures 4 and 5 show, for comparison, the maximum sound levels allowed from the site operations to residential receivers where there are “affected persons.”

Expected Sound Levels & Mitigation

Many types of engineering calculations can be done for a development project. Heating and air condition loads are calculated for a proposed use. The size of steel beams in a building and the depth of foundations may be calculated.

Likewise, engineering calculations can be made to analyze the various sound sources associated with a site and then predict both the resulting sound levels and the effects of various control measures, if any are needed.



How sound travels, reflects, etc. has been studied for well over a century. There are a multitude of formulas that describe the behavior of sound. For example, the sound from a small source decreases by 6 dB as the distance from the source doubles. However, for a roadway, which is generally considered to be a line source, not a point source, the sound decreases 3 decibels as distance doubles. Real-world projects are actually more complicated than this for large distances, many different sound sources, when terrain is taken into account, etc., but these two examples illustrate some basic concepts.

The methods we use for assessing how the various sound sources interact with the buildings, other reflective surfaces, terrain, distance, etc. are defined in the International Standard Organizations (ISO) Standard 9613-2:1996, the "Attenuation of Sound During Propagation Outdoors." This ISO standard is used worldwide.

In putting together a model we typically use a site plan drawing to provide dimensions and information about surrounding properties, elevations, equipment locations, travel routes and other useful information. We also collect information on various sound sources by obtaining manufacturer's information on the sound-generating characteristics of each source or making field measurements to determine how much sound a particular source (air conditioner, truck, etc.) makes. In some instances there are published tables of typical sound emissions characteristics of sources.

Given the acoustical characteristics of the sources, their locations (including elevation), the buildings (again, location and heights), reflecting surfaces, barriers and berms, terrain and elevation changes, ground cover and other characteristics sometimes unique to a site, the ISO 9613-2 calculations can be carried out to determine the sound levels at various receiver locations based on all these variables.

Often the calculations will be done over a wide area so that a sound level contour map can be created. In this case the calculations might literally involve thousands of receiver locations to do all of the mathematics necessary to calculate the sound levels at each of these points so a contour map can be developed. Running a particular model, because it can include so many calculations, might take just 5 or 10 minutes of computer time or it might take well over an hour.

When a moving sound source, such as a delivery truck traveling around a building is involved, the model has to do all of its calculations for the vehicle in a particular position, then mathematically move the truck a small distance and repeat the calculations, then move the truck again and repeat the calculations and so on. However, this method ensures that the sound level calculated at some receiver location is the maximum sound level (if that's what's being modeled) regardless of the truck's route; the closest distance to a receiver location may not be the loudest because of all the other factors besides distance. As the truck is moved in the model the sound reflections, barrier effects, etc. are taken into account, so at each and every step in the process we examine all of the factors of how the sound travels.

It is certainly possible to do these calculations by hand, but for even for a fairly simple layout of a few sources, a few buildings and reflecting surfaces, and a few receiver locations, and taking into account how each of these characteristics varies with the frequency of the sound, it would take many hours of time to manually calculate just one scenario.

Original Design

The proposed design includes a berm about ten feet high with a six feet high sound barrier on top, for a total net height of about 16 feet. This is shown on Figure 1.

Figures 6 through 8 show the maximum ("Lmax") A-weighted sound pressure levels from three different types of trucks. The smaller "box trucks" can operate at any time and meet the nighttime sound level limit of 50 dBA. The tractor-trailer sounds are a bit louder and meeting the nighttime limit is marginal, so QuickChek agreed to not have them making deliveries at night (10 PM to 7 AM). All of the truck deliveries will meet the applicable sound level limit for their time of operation. Sound data for these calculations comes from our own truck tests and the US DOT's Transportation Noise Model database for vehicle sound emissions; we used a speed of 20 MPH (probably high) for the levels.

Figure 9 shows the sound contribution from the rooftop air conditioning and refrigeration equipment. The resulting sound levels, assuming all the equipment is on at the same time, are well below the limits and the existing sound levels in the area.

The addition of the berm and barrier at the rear of the site has an additional benefit for the residences screened by the berm and barrier. It also blocks sounds from Route 130, which is the principal source of the ambient (background) sound.

Other Barrier Effects

Figure 10 shows the result of comparing the Route 130 traffic sounds with and without site development. We used the traffic volume figures from the Dolan & Dean traffic study and calculations based on the US DOT's Transportation Noise Model (TNM) to calculate sound levels over into the neighborhood from the traffic. We did this with no development on the site (no berm, barrier, building, or fuel canopy) and the proposed development. Figure 10 shows the differences in sound levels between the two scenarios, everything else being equal. Around the homes the sound levels from Route 130 are reduced 6 to 8 dBA; these are audible decreases.

Alternative Barrier

A berm ten feet high is at least 40 feet wide at the base with a two-to-one slope; at three-to-one it would be 60 feet wide. Questions were asked about reducing or eliminating the berm and locating the barrier (which would be taller to make up for the decreased berm height) closer to the QuickChek operations.

As a result, we examined the effects of a barrier 18 feet high located 12 feet from the curb line behind the QuickChek building and fuel canopy. This moves the berm back from the western side of the property and allows more of the existing vegetation to be undisturbed. (So the point is clear, the vegetation does not provide any meaningful sound reduction, so whether it remains or is removed does not alter the sound levels.) Figure 11 shows the barrier on the site plan.

Figures 12 through 14 so the results for the alternative barrier for the same three truck operations shown on Figures 6 through 8, in the same order.

Figure 15 is similar to what is discussed above regarding Figure 10 in that is shows the change in sounds from Route 130 in the residential area due to adding the 18-foot high barrier vs. the current undeveloped condition. The barrier casts an "acoustical shadow" into the neighborhood, reducing the highway sounds a noticeable amount.

We did not re-run the calculations for the rooftop equipment because the results would be similar.

Barrier Details

Sound barriers can be built in many different ways from many different materials. We want to clarify some important details so that the resulting barrier, whether on top of the berm or standalone, does what it needs to do.

Basically, the barrier needs to be solid (no small cracks or openings, such as a typical stockade fence would have). Wood barriers certainly can be built this way; see Figure 16, which comes from a State of Connecticut highway sound barrier design. To be clear, though, there are other designs; e.g., the wood planks could be horizontal. The important detail is that the joints between the boards are shiplap or T&G and the construction prevents twists in the boards. New Jersey builds sound barriers using various materials, including wood.

Making a barrier more massive once a certain mass is achieved does nothing to improve the sound reduction. The limiting factor is what sound goes over the top and/or around the ends of the barrier, not through it. Whether built from wood as shown, a commercial sound barrier product or 6 inches of concrete, a barrier of a given length and height will have the same sound attenuation, everything else being equal.

Yours truly,

Norman R. Dotti, PE, PP, INCE
Principal

NRD/me

enclosures

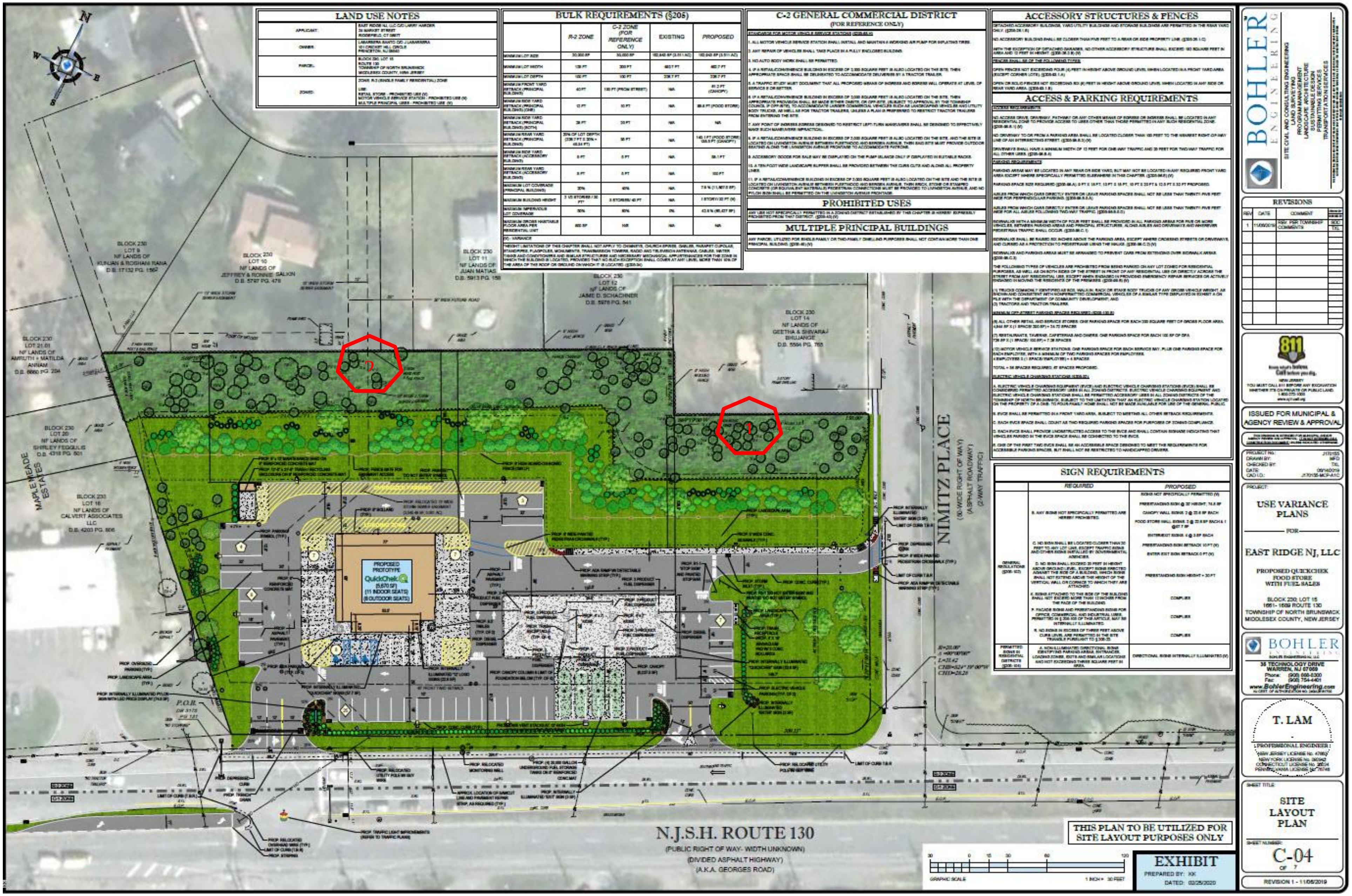


Figure 1 – Site Plan with Test Locations

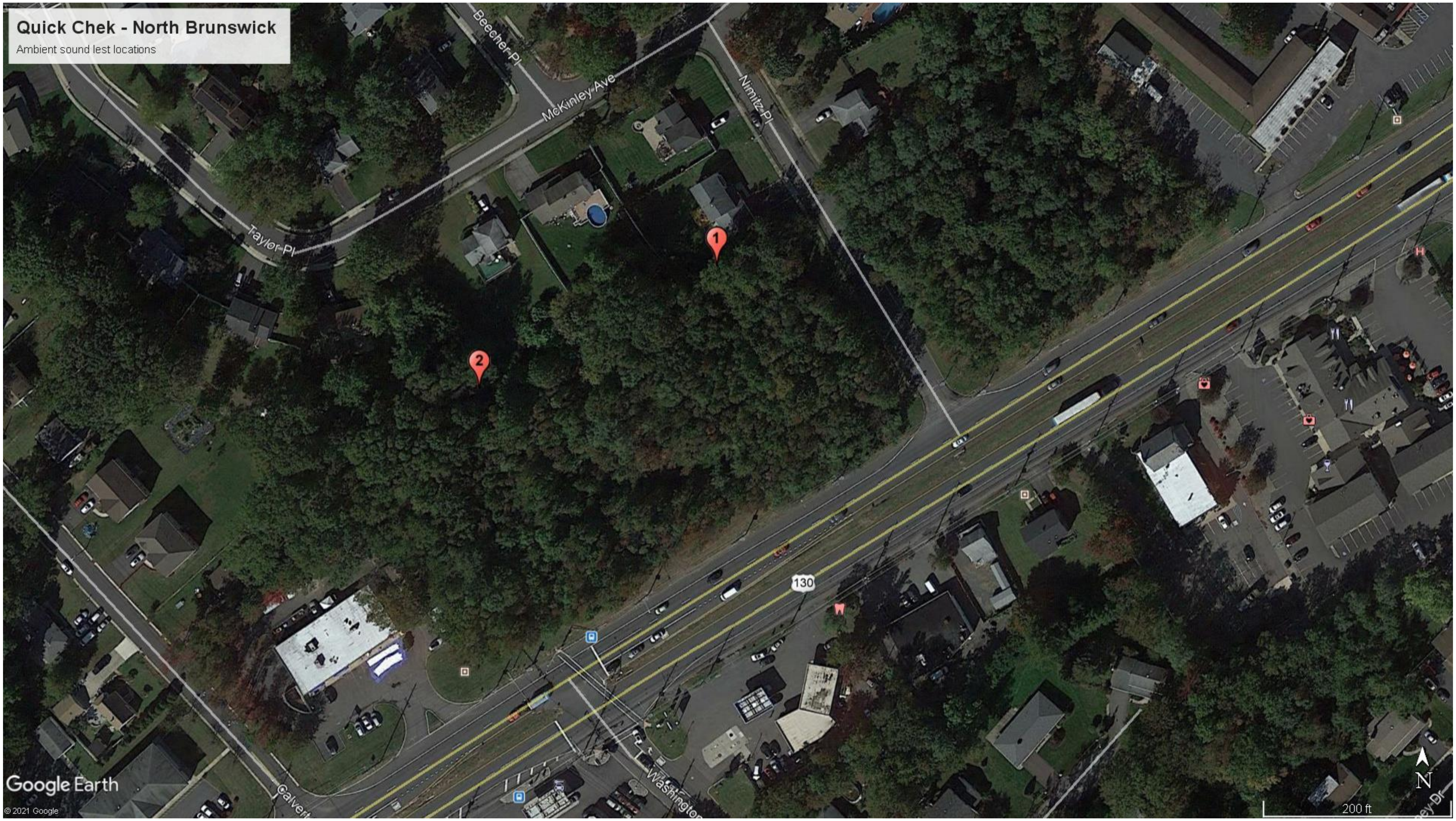


Figure 2 – Ambient Sound Tests

Long-term sound level monitoring is often done to establish the existing acoustical environment before (and sometimes after) a project is begun. It can be used to just document current conditions, to compare existing sounds to those expected from the new operation or to document compliance. Usually multiple monitors are set up around an area and run for at least several days. Weekdays and/or weekend days might be covered, depending on when the proposed use will be operating. These measurements of the "ambient" include all sounds, regardless of source.

Below is a typical ambient sound level graph with notes pointing out various features. Some versions of these graphs might be customized for a specific circumstance.

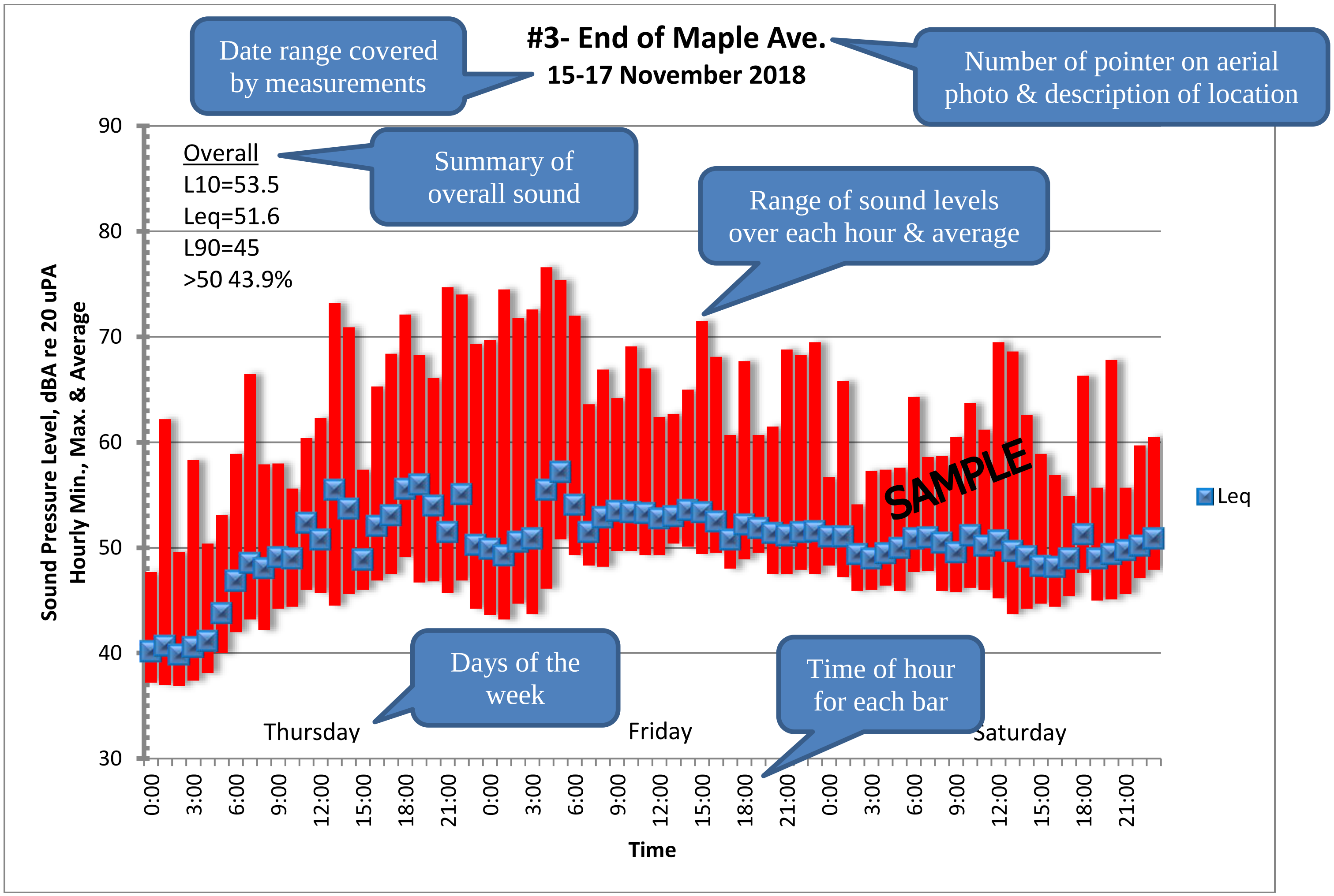
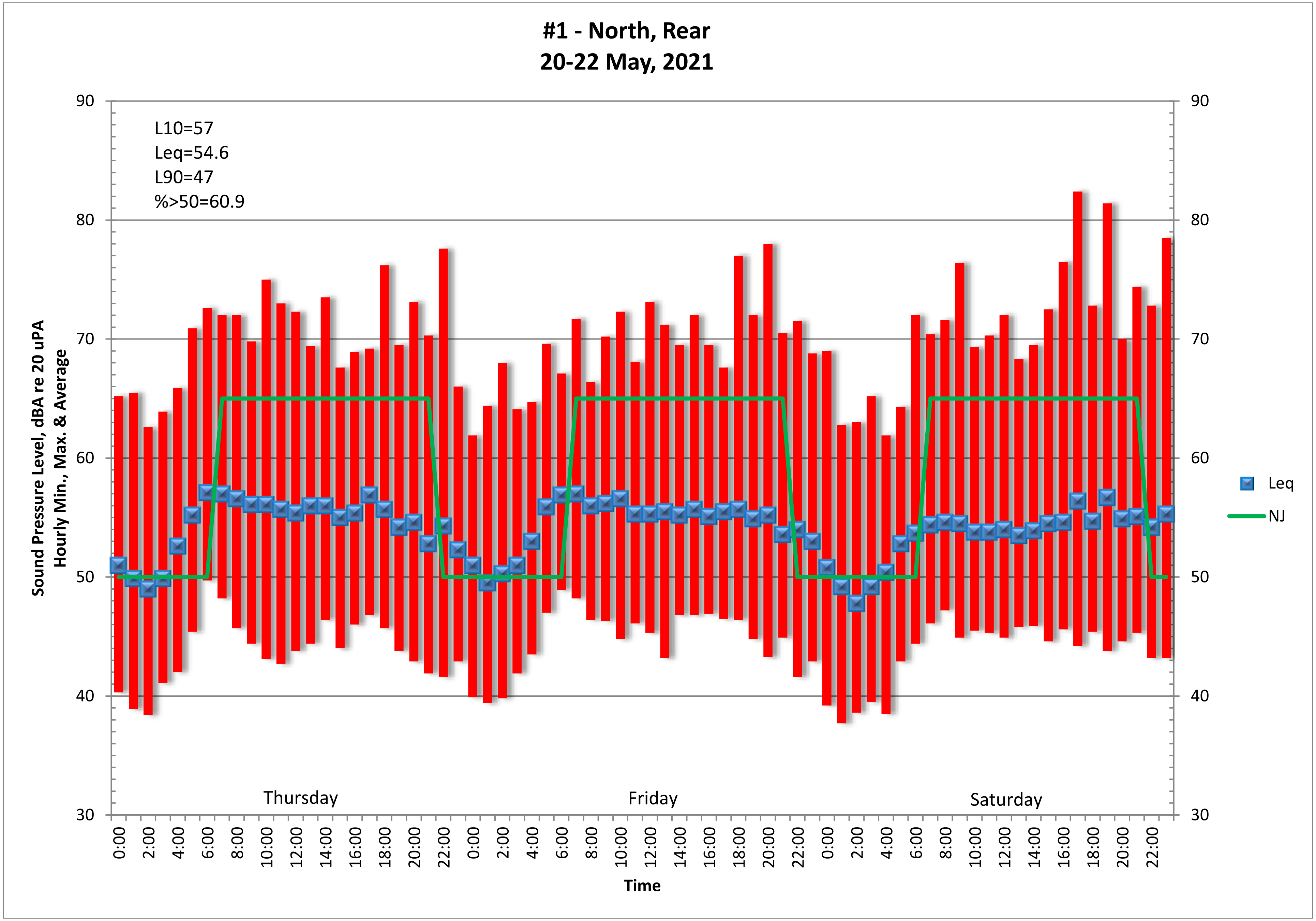


Figure 3



#1 - North, Rear
20-22 May, 2021
L10=57
Leq=54.6
L90=47
%>50=60.9
Sound Pressure Level, dBA re 20 uPA
Hourly Min., Max. & Average
90
80
70
60
50
40
30
Thursday
Friday
Saturday
0:00
2:00
4:00
6:00
8:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
Time
Leq
NJ

Figure 4

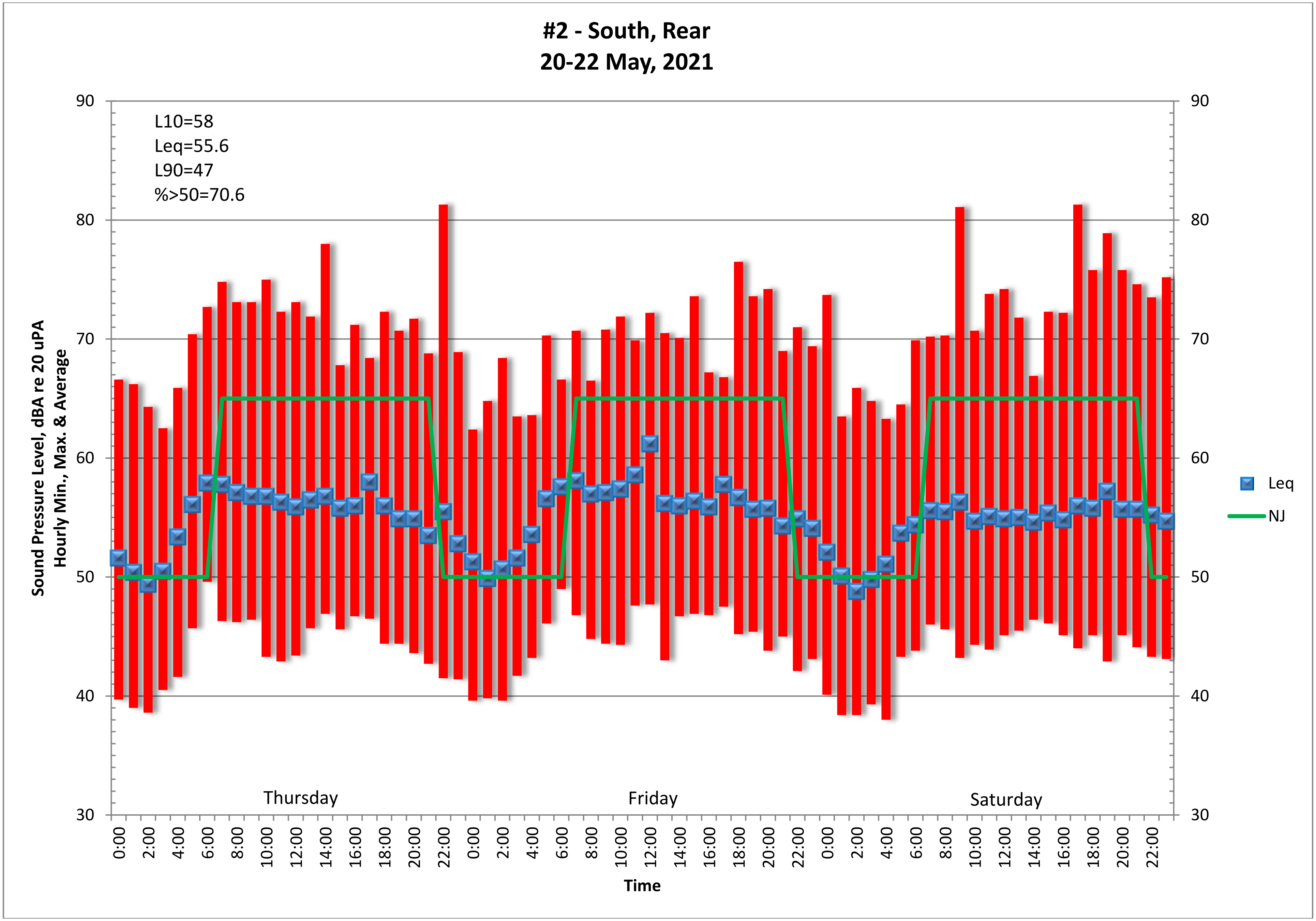

#2 - South, Rear
20-22 May, 2021
L10=58
Leq=55.6
L90=47
%>50=70.6
Sound Pressure Level, dBA re 20 uPA
Hourly Min., Max. & Average
Thursday
Friday
Saturday
Time
Leq
NJ

Figure 5

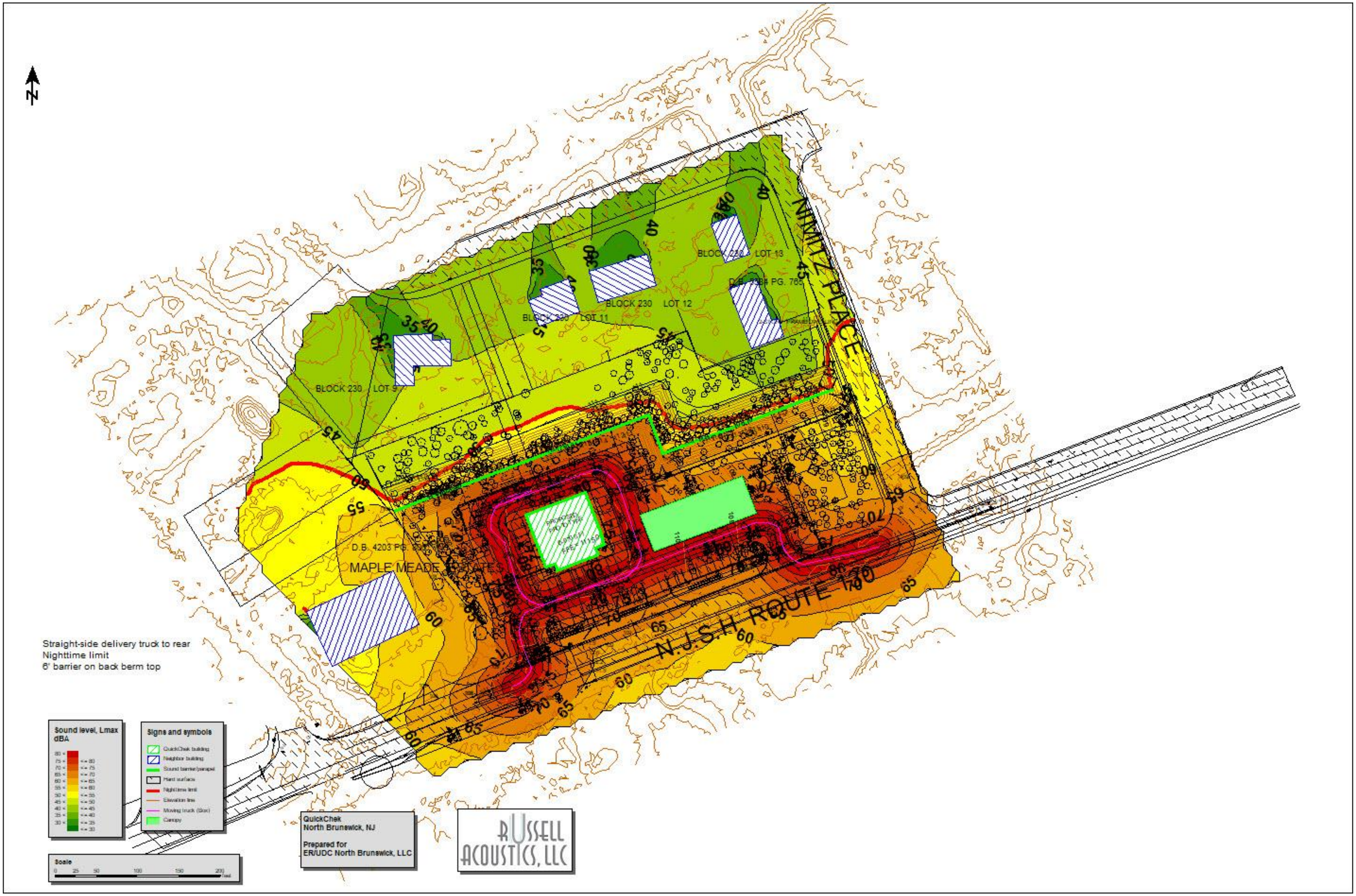


Figure 6 – Box Truck Delivery, Day & Night

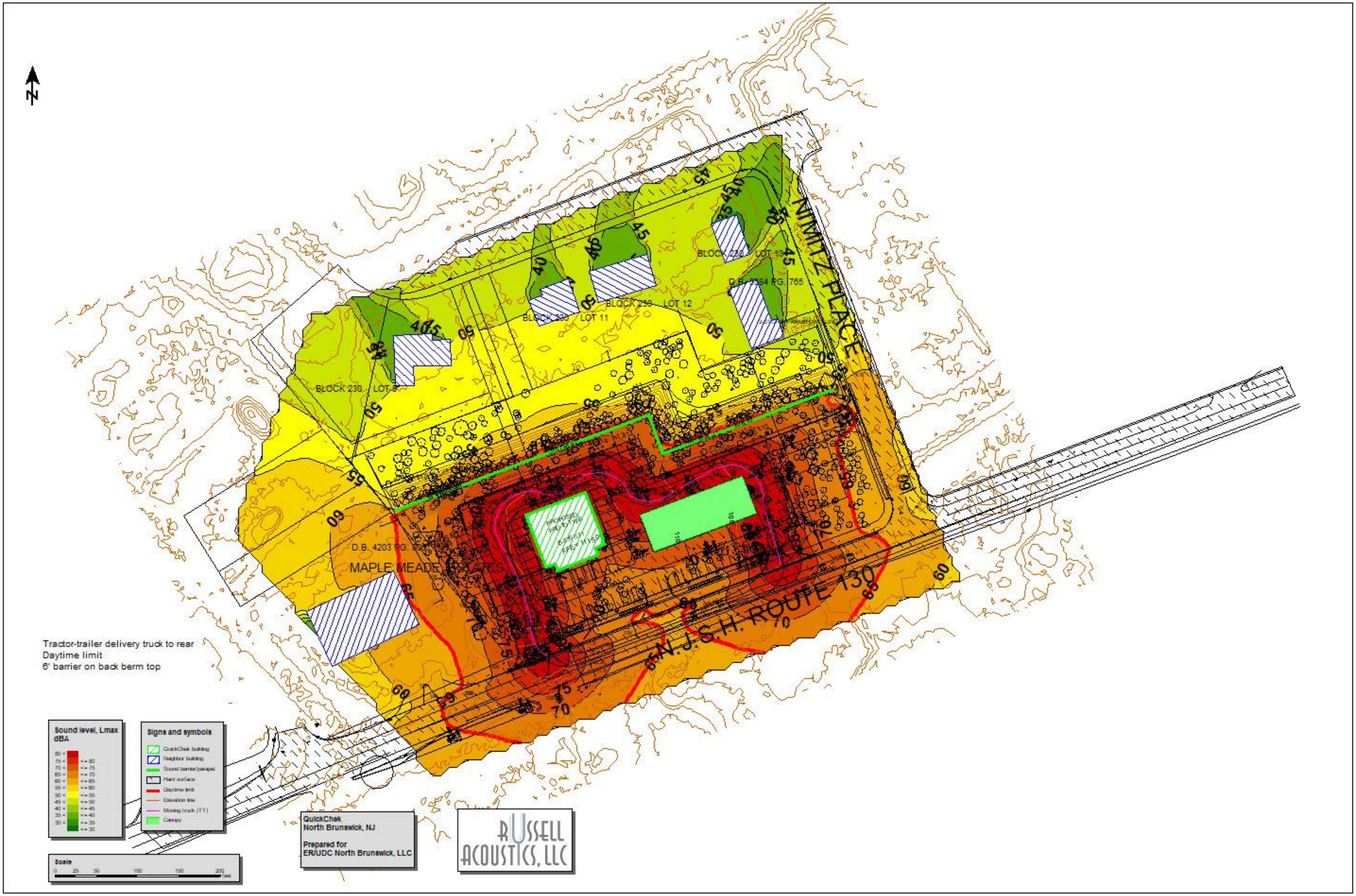


Figure 7 – Daytime Tractor Trailer Delivery

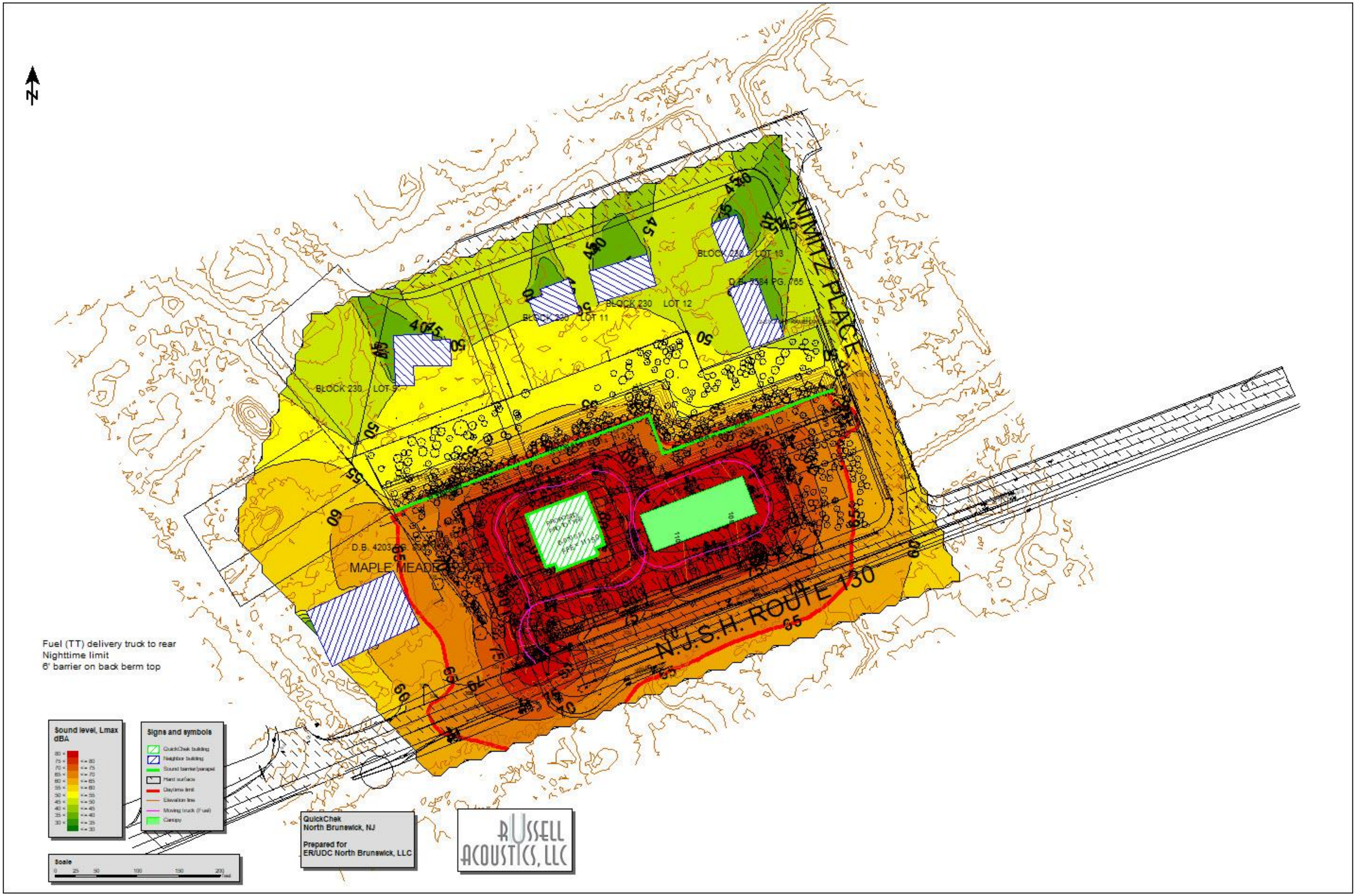


Figure 8 – Daytime Fuel Delivery

Figure 9 – Rooftop HVACR Equipment

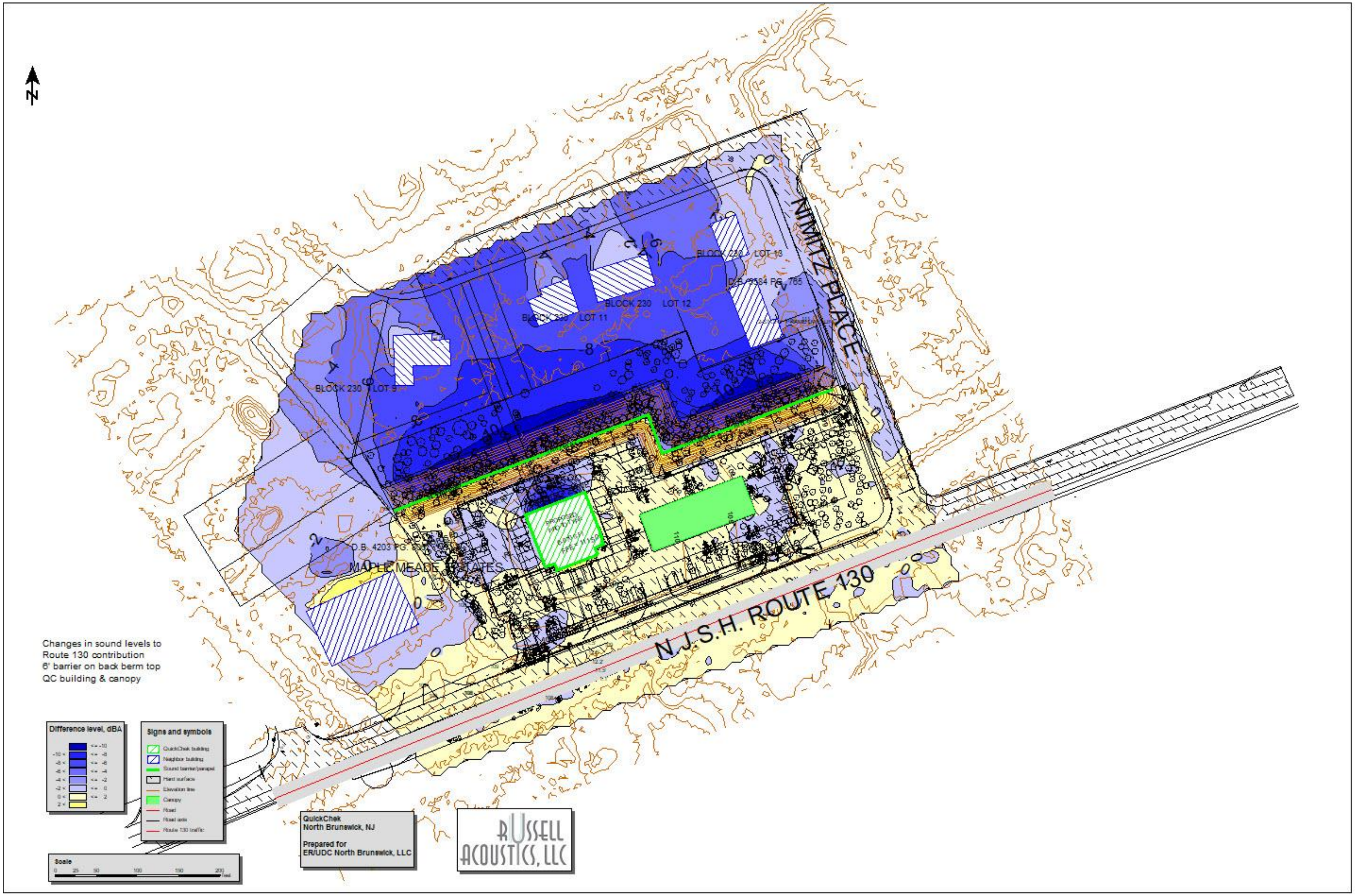


Figure 10 – Changes in Route 130 Traffic Sounds

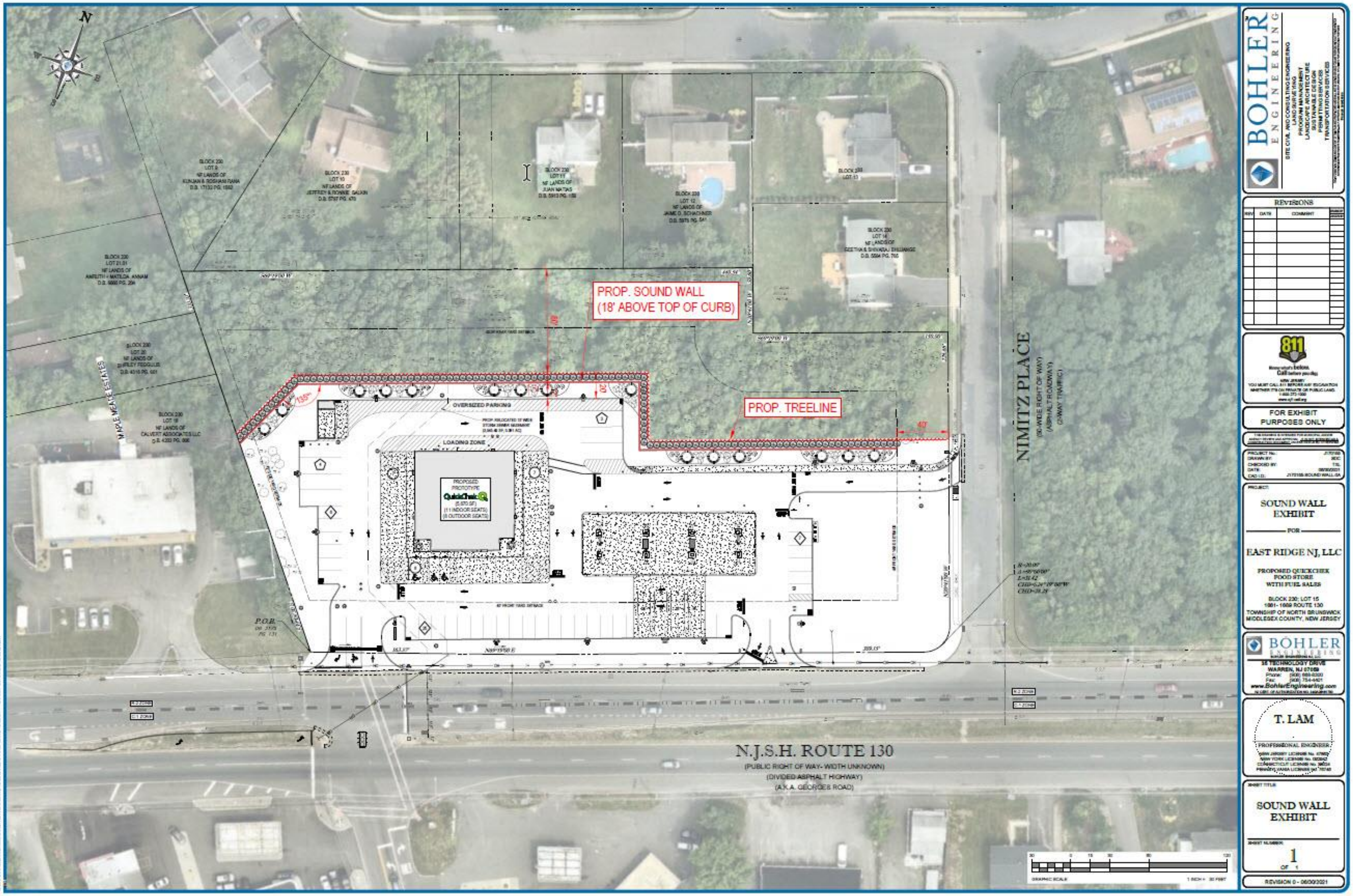


Figure 11 – Alternative Barrier Design

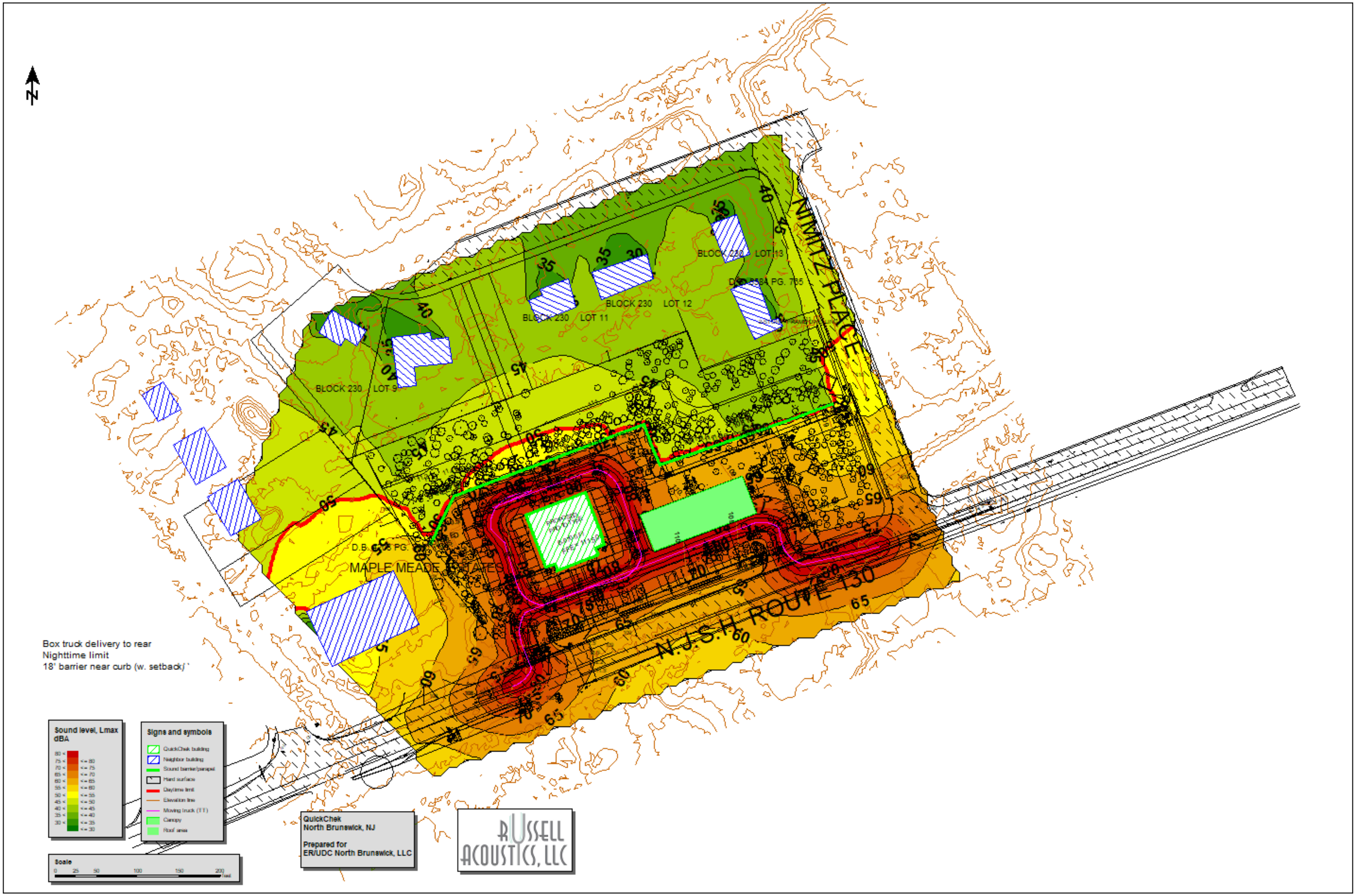


Figure 12 - Box Truck Delivery, Day & Night, Alternative Barrier

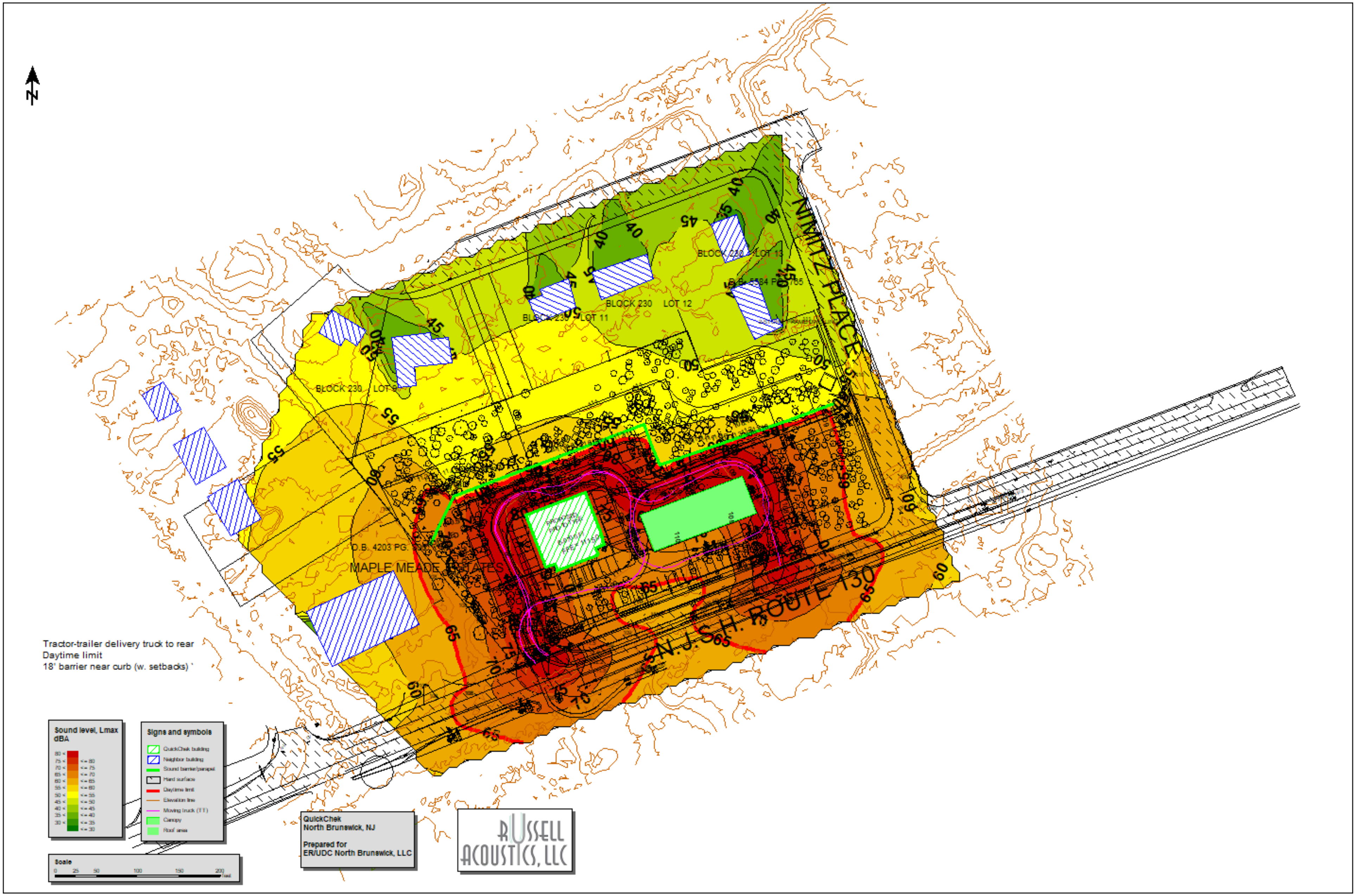


Figure 13 - Daytime Tractor Trailer Delivery, Alternative Barrier

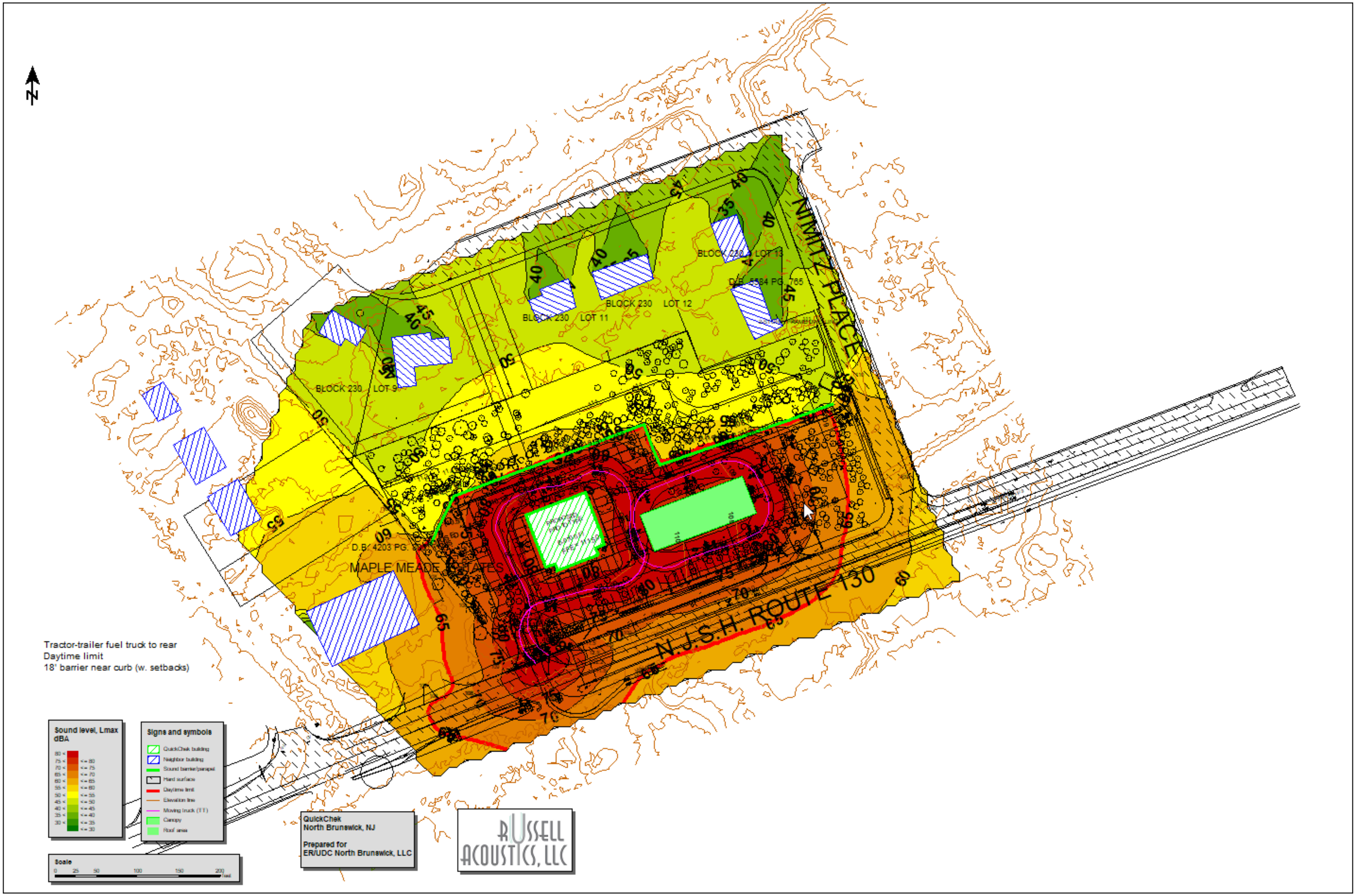


Figure 14 - Daytime Fuel Delivery, Alternative Barrier

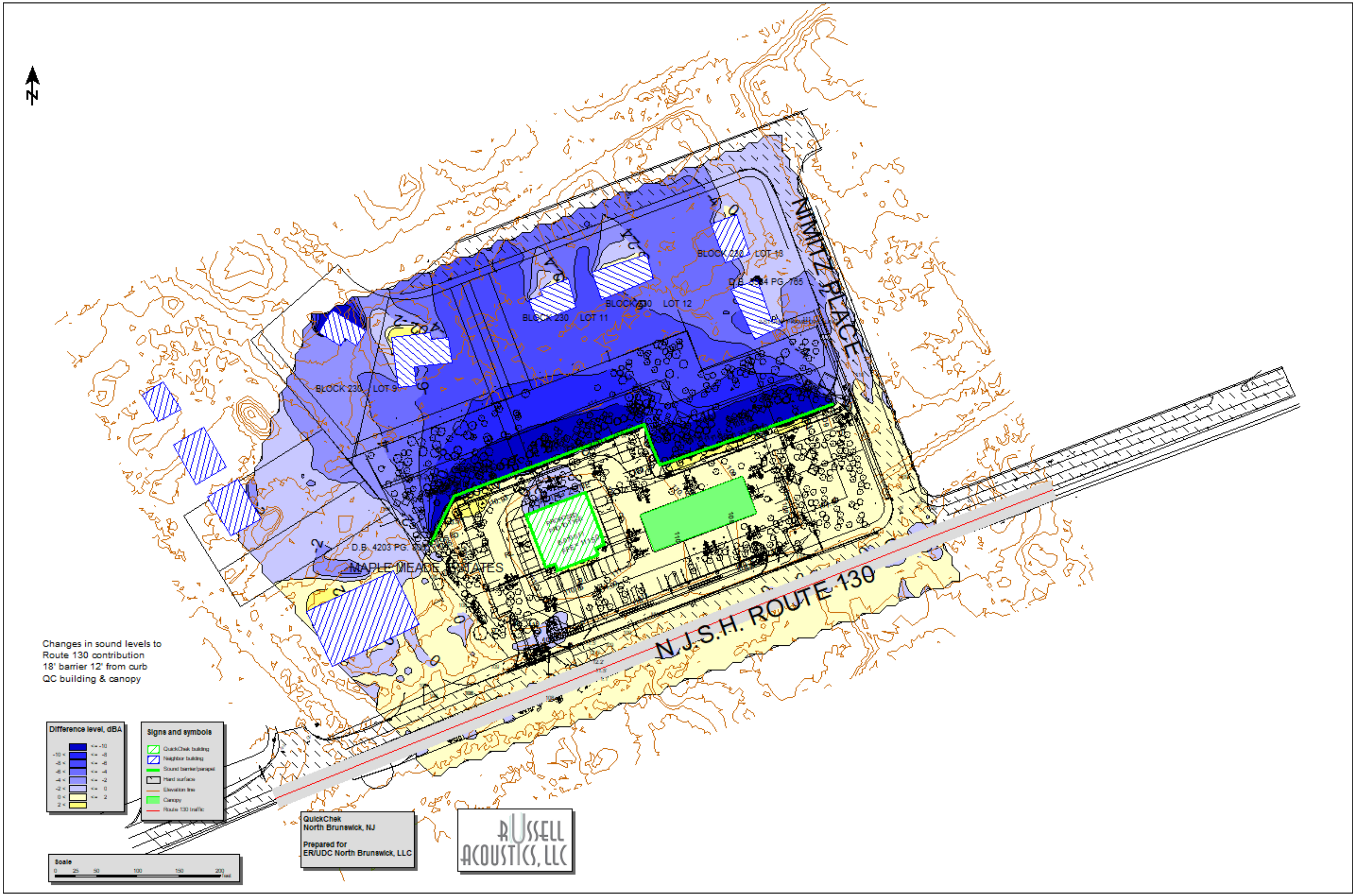
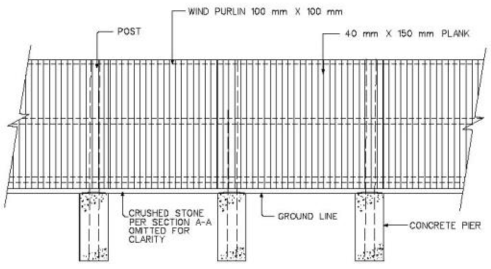
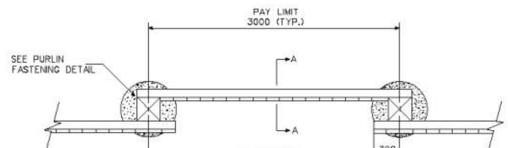


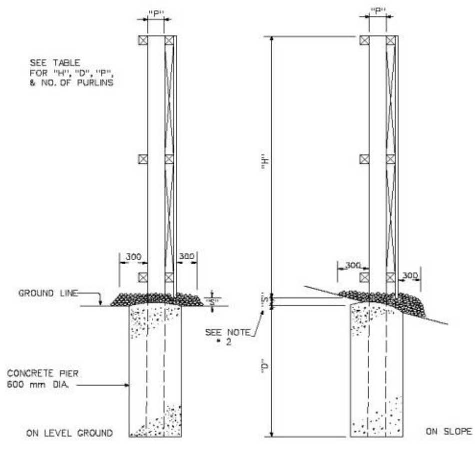
Figure 15 – Change in Route 130 Traffic Sounds (Berm only)



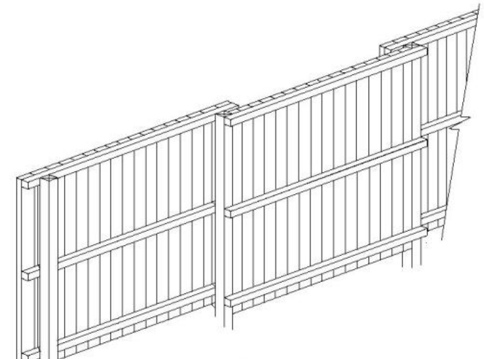
ELEVATION - TRAFFIC SIDE



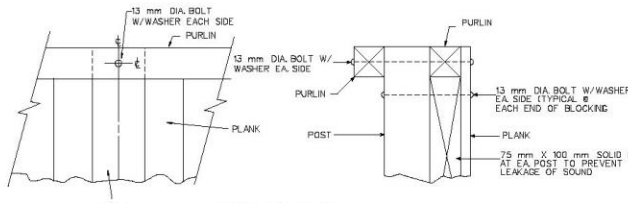
PLAN VIEW



SECTION A-A



ISOMETRIC VIEW - SIDE AWAY FROM HIGHWAY



PURLIN FASTENING

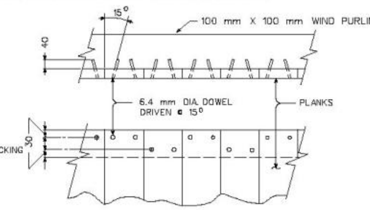
1. CONCRETE SHALL BE CLASS "A" IN CONFORMANCE WITH SECTION 6.01.
2. CRUSHED STONE SHALL CONFORM TO ARTICLE M.01.01 AND BE PLACED TO A MINIMUM DEPTH OF 50 mm ABOVE THE BOTTOM OF THE PANEL PLANKS. "S" SHALL BE A MINIMUM OF 50 mm.
3. ALL POST HARDWOOD MATERIAL SHALL BE BONGOSSI OR EKKI (LOPHERA ALATA/PROCERA). ALL PANAL HARDWOOD MATERIAL SHALL BE BONALIM (DINIZIA EXCELSA) OR EKKI WITH THE FOLLOWING MINIMUM CHARACTERISTICS:

	EKKI BONGOSSI	BONALIN
BENDING	25.9 MPa	26.2 MPa
TENSION	23.8 MPa	24.1 MPa
COMPRESSION PARALLEL TO GRAIN	24.5 MPa	27.6 MPa
COMPRESSION PERPENDICULAR TO GRAIN	13.8 MPa	14.5 MPa
SHEAR PARALLEL TO GRAIN	2.9 MPa	3.1 MPa
MODULUS OF ELASTICITY	17 170 MPa	16 200 MPa
MAX. UNIT MASS ASSUMED FOR DESIGN PURPOSES	1120 kg/m^3	1090 kg/m^3

4. THE HARDWOOD MATERIAL SUPPLIED SHALL BE NATURALLY FIRE-RESISTANT WITHOUT THE USE OF FIRE RETARDANT PRESERVATIVES. TEST RESULTS, CALCULATED IN ACCORDANCE WITH ASTM E-84 FOR FLAME SPREAD AND SMOKE DEVELOPED SHALL NOT BE MORE THAN THE FOLLOWING:

	EKKI BONGOSSI	BONALIN
FLAME SPREAD INDEX (10 MINUTES):	0	10
FLAME SPREAD INDEX (30 MINUTES):	10	25
SMOKE DEVELOPED VALUE (10 MINUTES):	5	10

5. THE TOP OF EACH POST IS TO BE FIELD CUT FLUSH WITH THE TOP OF THE PANEL PLANKS.
6. THE END PLANKS OF EACH PANEL SHALL NOT HAVE AN EXPOSED TONGUE OR GROOVE.
7. ALL FASTENERS SHALL BE STAINLESS STEEL OR HOT-DIPPED GALVANIZED IN ACCORDANCE WITH ASTM A153. DOWEL STEEL SHALL CONFORM TO ASTM A36. ALL OTHER HARDWARE SHALL CONFORM TO ASTM A307.



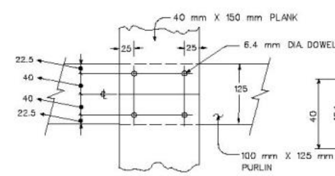
PLANK FASTENING

TABLE: POST AND PIER DEPTH "D" IN mm. (GRANULAR SOILS ONLY)

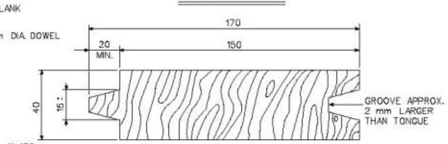
WALL HEIGHT "H" mm	POST DIMENSION "P" mm	NO. OF PURLINS mm	POST AND PIER DEPTH "D" CASE #1 mm	CASE #2 mm	CASE #3 mm
1800	150	3	1200	1800	1800
2400	170	3	1500	1800	2100
3000	190	3	1500	2100	2400
3600	210	3	1800	2400	2700
4200	240	3	2100	2700	3000
4800	260	4	2100	3000	3000
5400	280	4	2400	3000	3300
6000	300	4	2400	3300	3600
6600	320	4	2700	3600	3600

CASE #1: FLAT SURFACE WITH WATER TABLE BELOW BOTTOM OF HOLE.
CASE #2: FLAT SURFACE WITH WATER TABLE BELOW BOTTOM OF HOLE.
CASE #3: A SIDE SLOPE OF 1:2 WITH WATER TABLE BELOW BOTTOM OF HOLE.

NOTE: PLANKS UP TO 4800 mm IN LENGTH WILL BE PROVIDED AS ONE PIECE. PLANKS LONGER THAN 4800 mm MAY BE PROVIDED IN ONE LENGTH OR IN TWO LENGTHS WITH A SINGLE SPLICE. FOR WALLS OVER 4800 mm IN HEIGHT, IF SPLICES ARE USED, THE TWO INSIDE PURLINS WILL BE 100 X 125 TO ACCOMMODATE THE SPLICE. (SEE PLANK SPLICE DETAIL).



PLANK SPLICE DETAIL



PLANK SECTION

ALL DIMENSIONS ARE IN MILLIMETERS (mm) EXCEPT AS NOTED.

TEST CERTIFICATION REQUIRED--REF. ARTICLE 1.06.07
MATERIAL CERTIFICATE
1. LUMBER & POSTS
2. HARDWARE
A CERTIFICATE OF COMPLIANCE IS ALSO REQUIRED ON THE ABOVE ITEMS.

MANUAL REVISIONS TO THIS DOCUMENT ARE PROHIBITED. ALL REVISIONS MUST BE PERFORMED ON Cadd File: OSA2(200,200)9160.DGN

HARDWOOD NOISE BARRIER WALL
TYPE 2

CONN. DEPT. OF TRANSPORTATION 6/95
CONN. DEPT. OF TRANSPORTATION 6/95

916-D

Figure 16 – Typical Wood Sound Barrier