Appendix 14.1 – Noise Report

Bukojchani – Kichevo branch of the A2 highway

Construction and traffic noise study report

Contents

1 Introduction 3

2 Regulatory background 4

2.1 Existing situation regarding noise 5

2.1.1 Dwellings 5

2.1.2 Noise 5

3 Construction phase 7

4 Operational phase 10

5 Protection against excessive noise 16

APPENDIX 1 20

1 Introduction

The Bukojchani – Kichevo highway is a branch of the A2 motorway. The latter begins at the Miladinovci junction heading towards the Republic of Albania via Tetovo, Gostivar, Kichevo and Ohrid.

This particular branch, 12.73 km long, stretches through a mountainous region and therefore includes a number of infrastructure objects such as a double pipe tunnel, bridges, overpasses and culverts. The envisaged alignment passes near several settlements, but mostly at distances larger than 100 m.

Given the predicted rate of increase in traffic density, the noise it causes can be considerable. This report refers to the assessment of the environmental impacts of the noise pollution at the Bukovochani - Kichevo section of the A2 motorway

2 Regulatory background

The noise limits for different types of areas are defined in Art. 6 of the Rulebook on limit values of the level of noise in the environment (Official Gazette of the Republic of Macedonia No. 147/08 of 26.11.2008). They are listed in Table 1below.

Table 1 Noise limit values in individual areas

Видови реони	Ниво на бучава изразено во dB(A)		
	L_d	L_v	L_n
Реони изложени на интензивен патнички сообраќај	60	55	50
Реони изложени на интензивен железнички сообраќај	65	60	55
Реони изложени на авионски сообраќај	65	65	55
Реони со интензивна индустриска активност	70	70	70
Тивки реони надвор од агломерациите	40	35	35

In case the anticipated traffic noise levels exceed the target values, all practical safeguards should be applied to minimize the impact of noise. If, however, the expected noise levels are below the limit values, the reduction measures are reduced to a minimum.

In areas where the existing noise level is higher than the limit values, the limit values are considered as natural background.

The method for calculating the expected noise level of road traffic in Macedonia is determined by the Rulebook on the use of noise indicators, additional noise indicators, the method of noise measurement and assessment methods with the environmental noise indicators ("Official Gazette of the Republic of Macedonia "No. 107/08). However, the Rulebook is not consistent with which of the methods should be used in calculating or modeling the noise of road traffic. Details are given in chapter 3.2.

2.1 Existing situation regarding noise

2.1.1 Dwellings

This section of the highway will be constructed mainly outside of the settlements, but occasionally will pass near settlements like Zajas, Dolno Strogomishte and the city of Kichevo

The nearest house in the village of Zajas is about 70 meters away from the future highway. In Dolno Strogomishte, however, the distance from the closest houses is within 10-30 m. Accordingly, in some places the developer should take serious measures to protect against excessive noise from the construction activities on the highway.

2.1.2 Noise

Background noise was checked at 5 locations of different type (habitats, outlets and open space). Some of these receptors were used later in the noise model as individual points. Figure1 shows the locations of the individual points that are later encountered in the tables. The results of the noise measurements are shown in Table 2.

Table2 Existing level of noise at certain points along the route of the future highway

Мерно место	Координати (UTM)			dB(A)			
	X	Y	Период	Leq	Lmax	L10	L90
1	496915	4604978	Ден	54.6	72.1	57.9	39.1
			Вечер	52.3	70.8	54.6	40.2
			Ноќ	53.1	65.4	55.2	38.7
2	497144	4604935	Ден	78.1	102.8	52.7	31.6
			Вечер	76.6	81.3	61.3	39.7
			Ноќ	53.7	74.2	52.5	34.5
3	496839	4599105	Ден	71.5	87.6	76.2	45.8
			Вечер	60.0	79.7	63.4	46.2
			Ноќ	63.5	89.8	66.9	34.3
4	495334	4597970	Ден	45.8	64.7	49.2	38.3
			Вечер	51.6	67.3	54.3	39.5
			Ноќ	44.8	68.1	50.0	38.7
5	495180	4597509	Ден	44.3	65.1	46.5	33.0
			Вечер	67.3	94.2	52.9	46.2
			Ноќ	53.2	81.1	54.2	27.4

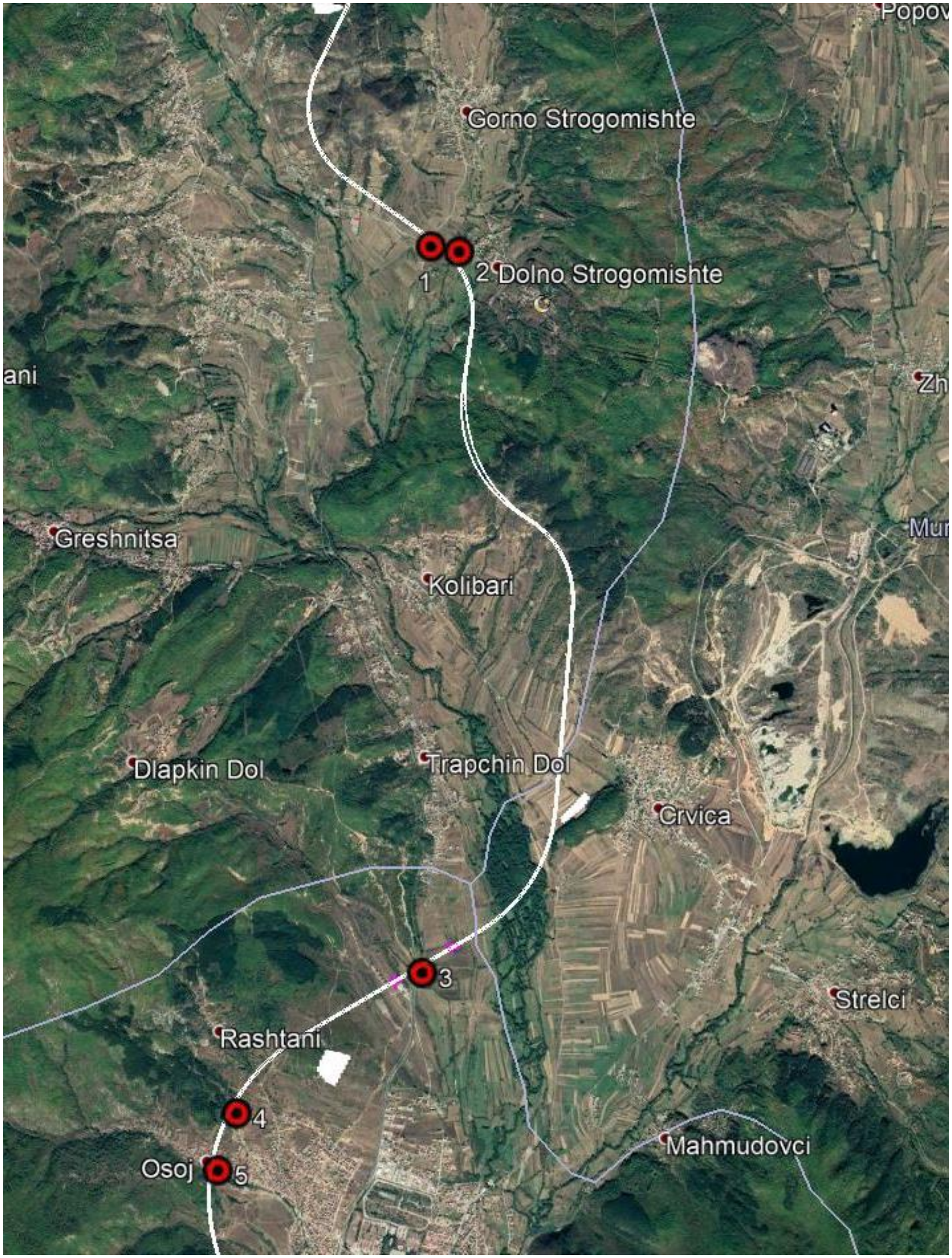

Figure1 Positions of measuring points along the alignment of the section of the highway from Bukocani to Kicevo

3 Construction phase

Road construction involves a range of activities that are significant sources of noise. Noise is generated by the equipment being used. Table 3 lists the machines most commonly used in road construction and the levels of noise they generate at a reference distance of 15 m from the source.

Table 3 Noise from construction equipment (15 m from the source)

Извори на бучава при градба	Ниво на бучава (dBA) на 15 m од изворот	Извори на бучава при градба	Ниво на бучава (dBA) на 15 m од изворот
Air compressor	81	Impact drill	101
Backhoe	80	Sonic drill	96
Pneumatic drill	88	Pneumatic tools	85
Truck	88	Pump	76
Compactor	82	Saw	90
Concrete mixer truck	85	Rock drill	98
Concrete pump truck	82	Валјак	74
Concrete compactor	76	Chain saw	76
Fixed crane	88	Shaker	83
Mobile crane	83	Scraper	89
Bulldozer	85	Shovel	82
Generator	81	Jogger	77
Grader	85	Cutter	84
Pneumatic hammer	85	Front end loader	85

Certainly, all stages of construction do not take place simultaneously. At each stage, operations involving various types of equipment, such as bulldozers, wood saws, trucks, etc., are included in the clearing of the field. Table 4 shows the typical types of equipment used in separate construction phases and the noise generated by the simultaneous use of all equipment, as well as the one generated by the planned use of the minimum necessary machinery

Се разбира дека сите фази на градба не се одвиваат едновремено. Во секоја од фазите се вклучени операции кои користат различни видови опрема како на пример булдозери, пили за дрво, камиони и сл. во расчистување на теренот. Во **Error! Reference source not found.** се прикажани типичните видови опрема која се користи во одделни фази на градбата и бучавата која се генерира при едновремено користење на целата опрема, како и онаа којашто се генерира со планско користење на минималната неопходна механизација.

Table 4 **Common noise levels in separate stages of road construction**

Activities	Noise from simultaneous use of the entire machinery	Noise when using minimum mechanization
Terrain clean-up	84	84
Excavation	89	79
Foundation	78	78
Construction	87	78
Finishing works	89	75

Extension of the noise is a logarithmic function and for a point source it is expressed as

$$L = L(ref) - 20 \cdot \log_{10}\left(\frac{D}{D_{ref}}\right) - 10 \cdot \log_{10}\left[G \cdot \left(\frac{D}{D_{ref}}\right)\right] \quad 1$$

Where:

L(ref)– Noise level at a reference distance from the source

D_{ref} – Reference distance from the source

D – Actual distance from the source

G - Terrain factor

The decrease in the noise level with the distance is lower for the noise of a linear source, for which the following expression is used:

$$L = L(ref) - 10 \cdot \log_{10}\left(\frac{D}{D_{ref}}\right) - 10 \cdot \log_{10}\left[G \cdot \left(\frac{D}{D_{ref}}\right)\right]$$

The noise during the construction period of the highway will have the character of a point source. This includes mobile activities such as excavating, compacting, etc. However, the intensive transport of materials along the access roads is treated as a linear source of noise.

Taking into account the highest values from Table 3 and disregarding the terrain factor, the most unfavorable scenario of noise propagation around the construction sites is set, according to which the diagram in Figure 2 is constructed.

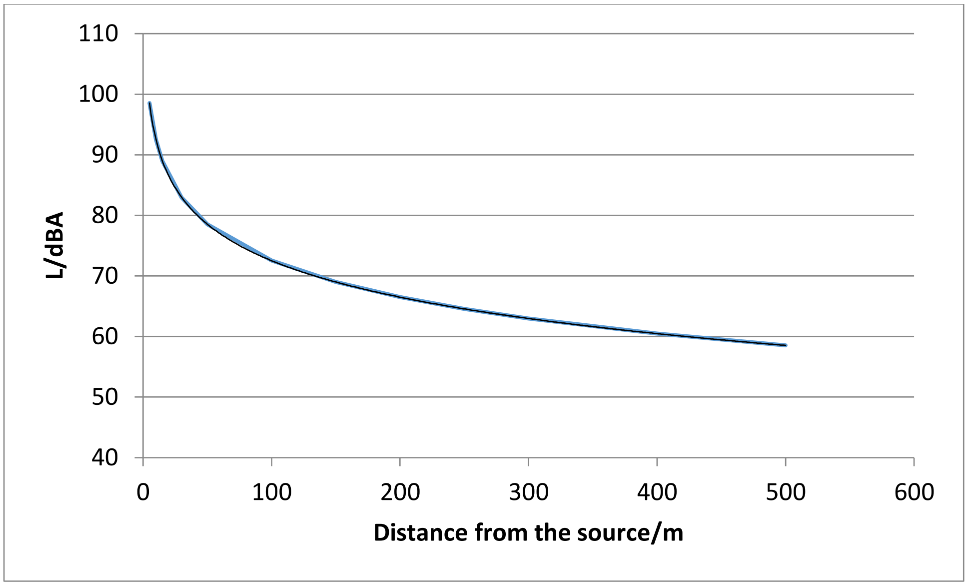

Figure 2 Attenuation of noise with the distance of the source

This part of the highway will be built on a completely new route, but mainly outside the inhabited areas, with no sensitive receptors. In addition, noise during construction is a nuisance of a temporary (short-term) nature, so the impacts are not significant except in the immediate vicinity of construction sites. The impacts at a distance of 400 m are within the limits of 60 dBA in the active period. Work overnight will be avoided, and in cases where this will not be possible, it will be reduced to a minimum, thus reducing the pressure on people in settlements.

The contractor should prepare a noise management plan for the construction period of this section of the A2 motorway (Gostivar - Kicevo), taking into account the location of each of the construction sites, the engaged machinery, the configuration of the terrain and the sensitivity of the receptors. Protection measures include, but are not limited to:

- Taking into account the possible noise impact when selecting the location of mobile bases
- Using a minimum number of construction machines at the a time
- Appropriate working time schedule
- Regular maintenance of the machinery aiming at noise emission reduction
- Sound insulation of equipment such as compressors and generators

If, by applying the primary measures, a satisfactory level of noise can not be achieved, the contractor shall set appropriate sound insulation barriers.

4 Operational phase

The impact of noise from road traffic depends on a number of factors, such as:

- Draffic density
- Types of vehicles and their speed
- Distance between the source and the receptor
- Height difference between the source and the receptor
- Characteristics of the terrain
- Meteorological conditions
- Background noise

Data on traffic density were taken from the Feasibility study for the highway as average annual daily traffic (AADT) (2021-2040). In the same set of data are those for the types of vehicles. A growth rate of traffic density of 5% has been adopted for the study. The predicted values are shown in Table 5. What is lacking in the data is the distribution of the number of vehicles per periods of the day.

Data and forecasts for the average annual daily traffic on the road Bukovochani - Kichevo

Table 5 Data and forecasts for the average annual daily traffic on the road Bukovochani - Kichevo

Year	Passanger cars	Freight vehicles	Total
2017	4602	1056	5658
2018	4832	1108.8	5941
2019	5074	1164.24	6238
2020	5327	1222.452	6550
2021	5594	1283.575	6877
2022	5873	1347.753	7221
2023	6167	1415.141	7582
2024	6475	1485.898	7961
2025	6799	1560.193	8359
2026	7139	1638.203	8777
2027	7496	1720.113	9216
2028	7871	1806.118	9677
2029	8265	1896.424	10161
2030	8678	1991.245	10669
2031	9112	2090.808	11202
2032	9567	2195.348	11763
2033	10046	2305.116	12351
2034	10548	2420.371	12968
2035	11075	2541.39	13617
2036	11629	2668.459	14297
2037	12210	2801.882	15012
2038	12821	2941.976	15763
2039	13462	3089.075	16551
2040	14135	3243.529	17379

Since no data on traffic density for individual periods of the day (day, evening, night) are available, the division was made according to the instructions in RLS 90 having in mind the share of freight vehicles indicated in the feasibility study.

Because the calculation method is described in detail in the Rulebook, for the purposes of this report, the German standard RLS 90 was applied. In addition, the SoundPlan Essential software package with the RLS 90 standard for calculations was used. Below are the basic characteristics, equations, and general correction factors used in calculations.

Corrections for average speeds of passenger and freight vehicles were calculated according to the speed limits of the section.

According to RLS 90, the level of noise from the road traffic at a reference distance from the source (25m) is determined, and then corrections are made for distance, height, speed, pavement, terrain and air:

Според RLS 90, се определува нивото на бучава од патниот сообраќај на референтна оддалеченост од изворот (25m), а потоа се вршат корекции за растојание, висина, брзина, коловоз, терен и воздух:

$$L_{d(eq)} = L_d^{25} + D_v + D_s + D_h + D_k + D_n$$

Where:

$L_{d(eq)}$ Equivaleny daily noise from traffic - dB(A)

D_v Correction for speed - dB(A)

D_s Correction for distance - dB(A)

D_h Correction for height - dB(A)

D_k Correction for pavement - dB(A)

D_n correction for slope - dB(A)

$L_{d,v,n}^{25}$ is calculated according to the equation

$$L_{d,v,n}^{25} = 37.3 + 10 \cdot \log[\mathrm{M} \cdot (1 + 0.082 \cdot \mathrm{p})]$$

Where,

M Number of vehicles on hourly basis for the particular period of the day (vehicles/hour) p Share of freight vehicles in percentages

The speed correction is determined by the following series of equations:

$$D_v = L_1 - 37.3 + 10 \cdot \log\left[\frac{100 + (10^{0.1 \cdot D} - 1) \cdot p}{100 + 8.23 \cdot p}\right]$$

$$L_1 = 27.7 + 10 \cdot log[1 + (0.02 \cdot v_1)^3]$$

$$L_2 = 23.1 + 12.5 \cdot log(v_2)$$

$$D = L_1 - L_2$$

Where v_1 and v_2 are the speeds of passenger and freight vehicles respectively (km/h).

By increasing the distance from the source of noise, the noise level of the receptor decreases. The distance correction is calculated according to the expression

$$D_r = 15.8 - 10 \cdot log(r) - 0.042 \cdot r^{0.9}$$

Where r is the distance between the source and the receptor (m).

Distances of the nearest traffic noise receptors have been determined according to the topographic map.

The height difference also has an effect on the level of noise in the receptor. In RLS 90, the height correction is calculated according to the equation

$$D_h = -4.8 \cdot e^{\left[-\frac{h}{r} \cdot \left(8.5 + \frac{100}{r}\right)^{1.3}\right]}$$

Where h is average difference in height (m).

The characteristics of the pavement have an impact and the correction is made according to values given in the Rulebook. For pavement with smooth asphalt the correction is -1 dB (A). This value is adopted for further calculations.

Following values have been used for slope correction:

$$D_n = 0.6 * |n| - 3 \qquad \text{за } |n| > 5\%$$

$$D_n = 0 \qquad \text{за } |n| \leq 5\%$$

The roughness and the type of terrain result in a certain reduction in noise. In these calculations no corrections were made for the terrain.

Table 6 shows the basic traffic data for 2021 and 2040

Table 6 Anticipated frequency of traffic in 2021 and 2040

	Day	Evening	Night
Estimated number of passanger cars in 2021	372.9	74.9	69.9
Estimated number of freight vehicles in 2021	74.9	48.2	24.1
Estimated number of passanger cars in 2040	942.3	165.2	82.6
Estimated number of freight vehicles in 20212040	189.2	121.7	60.8
Брзина на патнички возила	80	80	80
Брзина на товарни возила	80	80	80

Based od the data in Table 6 the sound levels at the referent distance of 25 meters have been determined (Table 7):

Table 7 Sound levels at a reference distance of 25 m

	Ld25	Le25	Ln25
2021	63.17	56.77	53.76
2040	67.99	63.19	58.97

Following values have been obtained for the common correction factors:

$D_{speed.d}$	$D_{speed.e}$	$D_{speed.n}$	D_{slope}	$D_{pavement}$	$D_{terrain}$
2.1	2.1	2.1	0	-1	0

Based on the estimated traffic density, calculations have been made for traffic noise levels in 2021 as well as for 2040. The results are presented in Table 8 and Table 9.

The results clearly indicate that the noise levels caused by the road traffic in this section of the highway exceed the noise limit values prescribed in the Rulebook on the use of noise indicators, additional noise indicators, the method of noise measurement and assessment methods with indicators for noise in the environment ("Official Gazette of the Republic of Macedonia" No. 107/08).

Table 8 Expected traffic noise levels from sensitive receptors in 2021

No.	km	Side	S (m)	hm (m)	D(h)	Ds	L_d	Lv	L_n	L_{den}
1	12+540	D	31.05	9.200	0.00	0.57	67.86	61.46	58.45	69.35
2	12+498	L	25.75	11.000	0.00	1.43	68.72	62.33	59.32	70.21
3	12+450	L	15.55	10.300	0.00	3.71	71.01	64.62	61.60	72.50
4	12+030	L	8.25	5.300	0.00	6.54	73.83	67.44	64.43	75.32
5	11+929	L	44.25	4.200	-0.60	-1.09	65.61	59.21	56.20	67.10
6	11+920	L	21.55	3.800	-0.03	2.24	69.50	63.11	60.10	70.99
7	11+910	L	14.25	2.300	-0.02	4.11	71.38	64.99	61.98	72.87
8	11+883	L	11.25	1.600	-0.01	5.16	72.44	66.05	63.04	73.93
9	11+765	L	21.05	1.200	-0.93	2.35	68.71	62.32	59.30	70.20
10	11+688	D	32.95	2.500	-0.78	0.29	66.81	60.42	57.40	68.30
11	11+799	D	20.55	1.100	-1.01	2.46	68.74	62.35	59.33	70.23
12	11+740	D	18.05	0.600	-1.71	3.04	68.62	62.23	59.22	70.12
13	11+725	D	17.75	0.600	-1.67	3.12	68.75	62.35	59.34	70.24
14	11+718	D	6.45	0.700	-0.01	7.63	74.92	68.52	65.51	76.41
15	11+490	L	69.95	0.500	-4.17	-3.30	59.83	53.44	50.42	61.32
16	11+426	L	46.05	2.900	-1.22	-1.28	64.79	58.40	55.39	66.28
17	11+418	L	9.65	5.400	0.00	5.85	73.14	66.75	63.73	74.63
18	11+398	L	16.65	7.200	0.00	3.41	70.70	64.31	61.30	72.19
19	11+383	L	39.15	7.700	-0.05	-0.51	66.73	60.33	57.32	68.22
20	2+840	L	54.45	3.200	-1.41	-2.08	63.80	57.41	54.40	65.29
21	2+810	L	23.250	3.400	-0.09	1.89	69.10	62.71	59.70	70.59
22	2+755	L	18.250	4.400	0.00	2.99	70.28	63.89	60.88	71.77
23	2+660	D	12.750	3.800	0.00	4.60	71.90	65.51	62.49	73.39
24	2+680	D	26.55	3.9	-0.11	1.29	68.48	62.08	59.07	69.97
25	2+758	D	51.95	17.3	0.00	-1.85	65.44	59.04	56.03	66.93

Table 9 expected traffic noise at sensitive receptors

No.	km	Side	S (m)	hm (m)	D(h)	Ds	L_d	Lv	L_n	L_{den}
1	12+540	D	31.05	9.200	0.00	0.57	71.88	65.49	62.48	73.37
2	12+498	L	25.75	11.000	0.00	1.43	72.75	66.35	63.34	74.24
3	12+450	L	15.55	10.300	0.00	3.71	75.03	68.64	65.63	76.52
4	12+030	L	8.25	5.300	0.00	6.54	77.86	71.47	68.45	79.35
5	11+929	L	44.25	4.200	-0.60	-1.09	69.63	63.24	60.23	71.12
6	11+920	L	21.55	3.800	-0.03	2.24	73.53	67.13	64.12	75.02
7	11+910	L	14.25	2.300	-0.02	4.11	75.41	69.02	66.00	76.90
8	11+883	L	11.25	1.600	-0.01	5.16	76.47	70.07	67.06	77.96
9	11+765	L	21.05	1.200	-0.93	2.35	72.74	66.34	63.33	74.23
10	11+688	D	32.95	2.500	-0.78	0.29	70.84	64.44	61.43	72.32
11	11+799	D	20.55	1.100	-1.01	2.46	72.76	66.37	63.36	74.25
12	11+740	D	18.05	0.600	-1.71	3.04	72.65	66.26	63.24	74.14
13	11+725	D	17.75	0.600	-1.67	3.12	72.77	66.38	63.37	74.26
14	11+718	D	6.45	0.700	-0.01	7.63	78.94	72.55	69.54	80.43
15	11+490	L	69.95	0.500	-4.17	-3.30	63.85	57.46	54.45	65.34
16	11+426	L	46.05	2.900	-1.22	-1.28	68.82	62.42	59.41	70.31
17	11+418	L	9.65	5.400	0.00	5.85	77.16	70.77	67.76	78.65
18	11+398	L	16.65	7.200	0.00	3.41	74.73	68.33	65.32	76.22
19	11+383	L	39.15	7.700	-0.05	-0.51	70.75	64.36	61.35	72.24
20	2+840	L	54.45	3.200	-1.41	-2.08	67.83	61.44	58.42	69.32
21	2+810	L	23.250	3.400	-0.09	1.89	73.13	66.73	63.72	74.62
22	2+755	L	18.250	4.400	0.00	2.99	74.31	67.92	64.90	75.80
23	2+660	D	12.750	3.800	0.00	4.60	75.92	69.53	66.52	77.41
24	2+680	D	26.55	3.9	-0.11	1.29	72.50	66.11	63.10	73.99
25	2+758	D	51.95	17.3	0.00	-1.85	69.46	63.07	60.06	70.95

5 Protection against excessive noise

The criterion for deciding on the need to apply measures for reducing the noise level is the Law on Limit Values of the Environmental Noise Level (Official Gazette of RM 147/2008). Limit values for areas exposed to certain activities are given In Art. 6 of the Rulebook. These values are provided in Table 10 below. The values from the highlighted line (Regions exposed to intense road traffic) are used for determination of the barrier characteristics.

Table 10 Sound limit values outside urban areas

Type of region	Sound level dB(A)		
	Ld	Le	Ln
Regions exposed to intense road traffic	60	55	50
Regions exposed to intense railway traffic	65	60	55
Regions exposed to intense air traffic	65	65	55
Regions exposed to intense industrial activities	70	70	70
Quiet regions outside agglomerations	40	35	35

Measures to reduce the level of noise in the environment include but are not limited to:
• Setting sound barriers wherever there is a need,
• Speed limitation through sensitive locations
• Choosing the asphalt mix on the carriageway (quiet pavement)
• Using "silent tires" etc.

Among the most widespread noise protection measures is the setting of sound barriers between the source of noise and the receptor. The rule is that the barrier height is at least 30% higher than the height by which the barrier touches the line between the source and the receptor. Accordingly, the distance of the barrier from the source of noise affects its height. The barriers are planned at a distance of 13.5 to 14 m from the axis of the road. Below are the basics of barrier calculations.

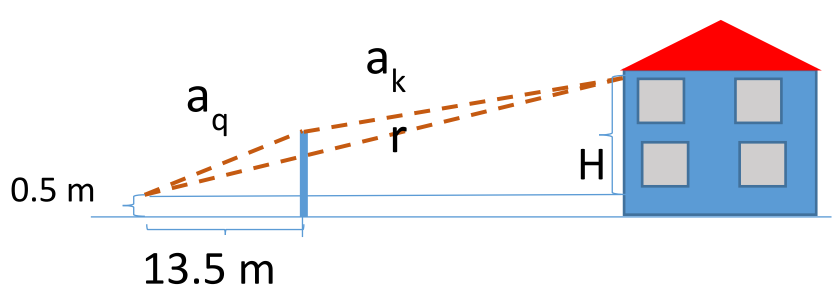

Figure 3 Geometry items for determination of sound protection barriers

The noise reduction as a result of the sound protection barrier is calculated according to the equation

$$D_b = 7 \cdot lg\left[5 + \left(\frac{70 + 0.25 \cdot r}{1 + 0.2 \cdot z}\right) \cdot z \cdot K_w^2\right]$$

Where:

K_w	sound reduction due to terrain and meteorological conditions
$z = a_Q + a_A - r$	difference of the path length between the sound beam through the barrier and the one scattered at the top of the barrier.
a_Q	Distance from the source to the top of barrier
a_A	Distance from the top of barrier to the receptor
r	Shortest distance from the source to the receptor

If the barrier does not cover the optical line between the source and the receptor, then z_k receives a negative value because the scattered beam adds the direct one.

Weather correction

$$K_w = e^{-\frac{1}{2000} \cdot \sqrt{\frac{a_Q \cdot a_A \cdot r}{2 \cdot z}}}$$

3a $z_k < 0$ $K_{w,\kappa}=1$

For financial reasons (investment and maintenance costs), sound barriers are only offered at places that cover a larger number of dwellings with a certain length before and after the buildings. In locations where no additional space is available, such as bridges, barriers are provided just behind the flexible bumpers at a distance of 12.5 m from the axis of the motorway.

Applying the described method of calculation, the required heights of sound barriers in certain locations have been determined. The barriers are set at a distance of 13.5 m from the axis of the motorway. The results are given in Table 11.

Where a need for sound protection barrier was determined, a minimum height of 2 m was adopted. Only on two locations a need for higher barriers was detected.

Table 11 Calculated barrier heights at sensitive receptors

No.	km	Side	C(m)	DH	h-0.5	Calculated barrier height	Adopted barrier height	z	Kw	Dz
23	2.66	D	12.75	-3.8	-0.67	0.33	2	2.13	1.00	14.38
24	2.68	D	26.55	-3.9	-0.33	0.67	2	2.26	0.99	14.61

25	2.758	D	51.9	-17.3	-0.75	0.25	2	2.07	0.98	14.62
10	11.7	D	32.95	2.5	0.17	1.17	2	2.69	0.99	15.00
14	11.718	D	6.45	0.7	0.24	1.24	2	2.68	1.00	14.79
13	11.725	D	17.75	0.6	0.08	1.08	2	2.70	0.99	14.89
12	11.74	D	18.05	0.6	0.07	1.07	2	2.70	0.99	14.89
11	11.799	D	20.55	1.1	0.12	1.12	2	2.70	0.99	14.91
1	12.54	D	31.50	9.2	0.66	1.66	2	2.53	0.99	14.87
22	2.755	L	18.25	-4.4	-0.54	0.46	2	2.19	0.99	14.48
21	2.81	L	23.25	-3.4	-0.33	0.67	2	2.26	0.99	14.58
20	2.84	L	54.45	-3.2	-0.13	0.87	2	2.30	0.98	14.84
19	11.383	L	39.15	7.7	0.44	1.44	2	2.62	0.99	14.99
18	11.398	L	16.65	7.2	0.97	2.1	3	2.34	0.99	14.61
17	11.418	L	9.65	5.4	1.26	2.26	3	2.15	1.00	14.38
16	11.426	L	46.05	2.9	0.14	1.14	2	2.70	0.98	15.09
15	11.49	L	69.95	-0.5	-0.02	0.98	2	2.30	0.98	14.94
9	11.765	L	21.05	-1.2	-0.13	0.87	2	2.30	0.99	14.60
8	11.883	L	11.25	-1.6	-0.32	0.68	2	2.26	1.00	14.49
7	11.91	L	14.25	-2.3	-0.36	0.64	2	2.25	0.99	14.51
6	11.92	L	21.55	-3.8	-0.40	0.60	2	2.24	0.99	14.55
5	11.929	L	44.25	-4.2	-0.21	0.79	2	2.29	0.98	14.76
4	12.03	L	8.25	-5.3	-1.45	0.45	2	1.61	1.00	13.76
3	12.45	L	15.55	-10.3	-1.49	0.49	2	1.53	0.99	13.71
2	12.498	L	25.80	-11	-0.96	0.04	2	1.94	0.99	14.30

However, the software calculations have shown that some of the barriers should be much higher than previously determined. In addition, bigger barrier lengths have been determined due to the characteristics of the terrain and the pavement.

Barrier locations on this branch of the highway, their lengths and heights are displayed in Table 12.

Table 12 Locations where sound barriers are required

Stationing		Side	Length	Height
From	To			
2+640	2+780	Десна	140	2
2+800	3+020	Лева	220	3
11+331	11+471	Лева	140	4.5
11+471	11+529	Лева	58	2
11+701	11+885	Десна	184	3
11+723	11+912	Лева	189	2
12+020	12+051	Лева	31	2
12+343	12+528	Лева	185	2

Sound barriers should have the following characteristics:

1. Have a sound absorption coefficient of at least 8 dB (A) (EN 1793-1)
2. The aerial sound insulation under direct conditions of the sound field shall not be less than 28 dB (A) (Class D3 EN 1793-6)
3. To resist atmospheric influences (temperatures from -30 to + 70 ° C, humidity and wind)
4. To be resistant to the dynamic force of the snow that is discharged when cleaning it from the pavement (EN 1794-1)
5. Be resistant to impacts of stones and scrap (Class 3 - EN 1794-2)
6. To be water-resistant, salt and the effect of combustion gases
7. To be resistant to fire from plants (class 3 - EN 1794-2)
8. Be resistant to the cumulative effects of the above factors
9. The specified characteristics should be confirmed by an appropriate attestation.
10. To have a long life of exploitation and low maintenance costs
11. In order to protect the landscape, it should be in bright pastel colors
12. If the developer decides to set up transparent sound barriers, they should have clear warning signs for birds.

APPENDIX 1

Graphical presentations of the noise levels at sensitive receptors along the Bukocjani – Kichevo branch of the A2 highway for AATD in 2040

Table 13 Noise at sensitive receptors (Sound Plan Essential calculation) along the highway between stationing 2+780 and 2+940

No.	Coordinates			Limit			Level w/o NP			Level w. NP			Difference			Conflict		
	X	Y	Floor	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
	7497346.5	4605857.3		dB(A)			dB(A)			dB(A)			dB(A)			dB(A)		
1	7497346.5	4605857.3	GF	60	55	50	64	60.3	57.3	55.7	52	48.3	-8.3	-8.3	-8.3	-	-	-
1	7497356.5	4605832.8	1.Fl	60	55	50	67.8	64	61	57	53.3	48.7	-10.8	-10.7	-10.8	-	-	-
2	7497356.5	4605832.8	GF	60	55	50	64.6	60.9	57.9	51.9	48.2	44.5	-12.7	-12.7	-12.7	-	-	-
2	7497397.3	4605766.7	1.Fl	60	55	50	69.5	65.7	62.7	55.5	51.8	48.1	-14	-13.9	-13.9	-	-	-
3	7497397.3	4605766.7	GF	60	55	50	64.6	60.9	57.8	57.3	53.6	47.9	-7.3	-7.3	-7.3	-	-	-
3	7497458.3	4605836.6	1.Fl	60	55	50	65.7	62	58.9	58.2	54.4	46.4	-7.5	-7.6	-7.5	-	-	-
4	7497458.3	4605836.6	GF	60	55	50	64.5	60.7	57.7	58.2	54.4	49.1	-6.3	-6.3	-6.3	-	-	-
4	7497503.2	4605801.5	1.Fl	60	55	50	67	63.2	60.2	59.6	55.8	49.4	-7.4	-7.4	-7.4	-	0.8	-
5	7497503.2	4605801.5	GF	60	55	50	65.4	61.7	58.7	55.3	51.6	47.9	-10.1	-10.1	-10.1	-	-	-
5	7497497.2	4605828.9	1.Fl	60	55	50	70	66.2	63.2	56.4	52.7	49	-13.6	-13.5	-13.5	-	-	-
6	7497497.2	4605828.9	GF	60	55	50	66.9	63.2	60.2	56.6	52.8	49.1	-10.3	-10.4	-10.4	-	-	-
6	7497535.4	4605804.3	1.Fl	60	55	50	67.7	63.9	60.9	58.8	55.1	51.4	-8.9	-8.8	-8.8	-	0.1	1.4
7	7497535.4	4605804.3	GF	60	55	50	65.7	61.9	58.9	56.9	53.2	49.5	-8.8	-8.7	-8.7	-	-	-
7	7497549.4	4605798.5	1.Fl	60	55	50	66.6	62.8	59.8	57.3	53.6	49.9	-9.3	-9.2	-9.2	-	-	-
8	7497549.4	4605798.5	GF	60	55	50	64.7	61	57.9	55.4	51.7	48	-9.3	-9.3	-9.2	-	-	-
8	7497549.4	4605798.5	1.Fl	60	55		65.7	59	67.3	57.2	53.8	49.1	-8.5	-8.5	-8.5	-	-	

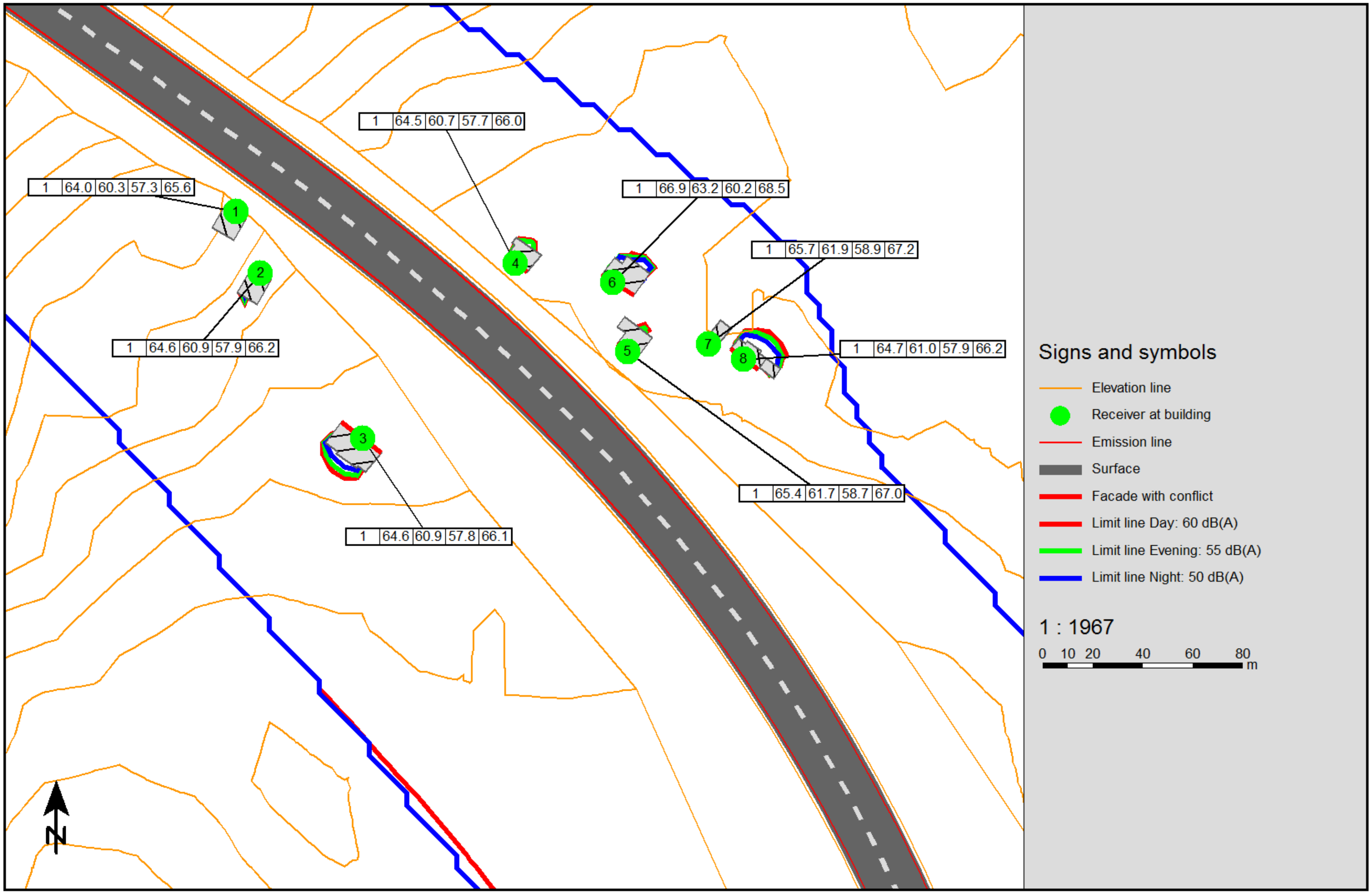

Figure 4 Single point noise levels between stationing 2+780 и 2+940 without noise protection barriers

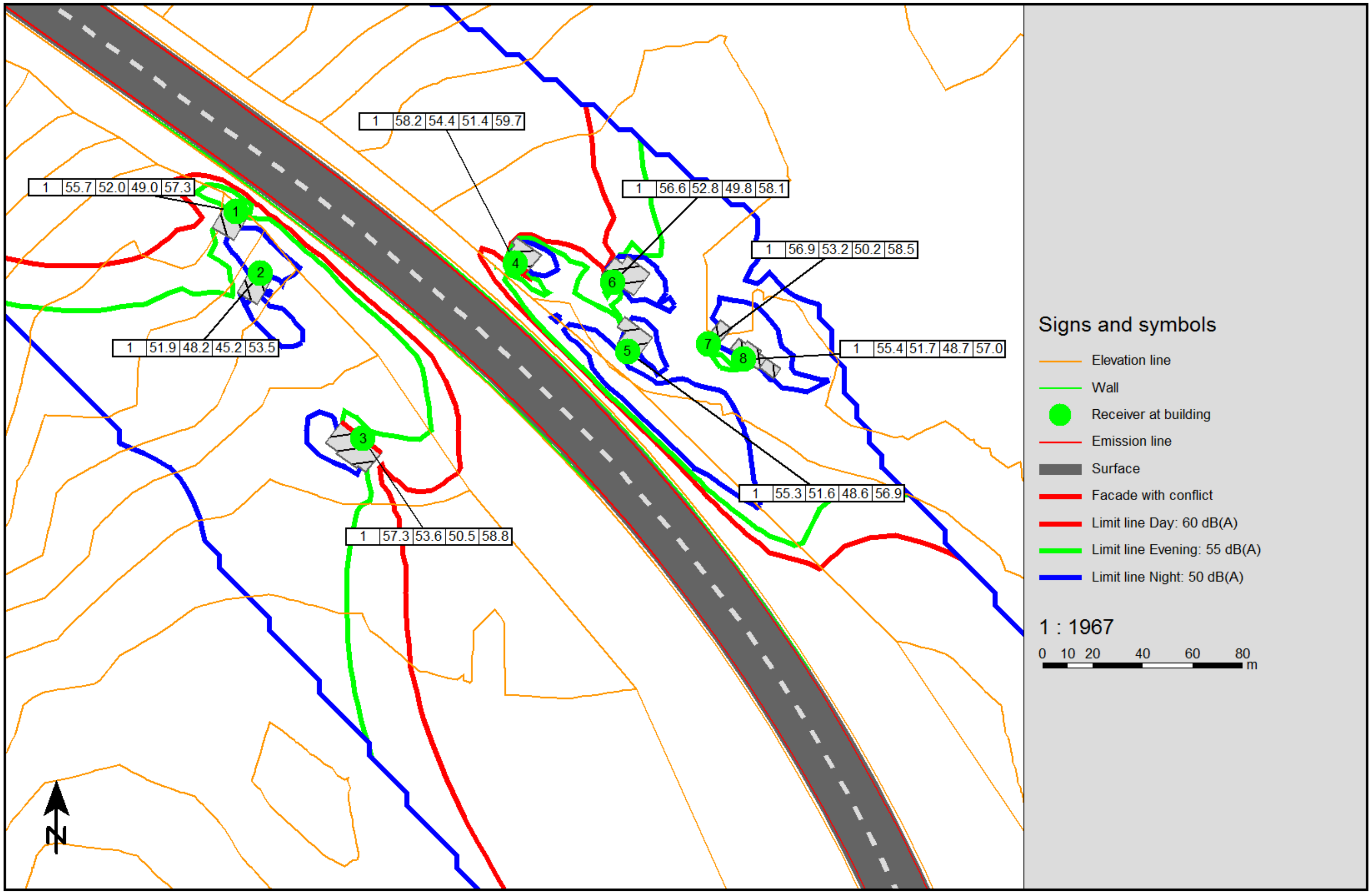

Figure 5 Single point noise levels between stationing 2+780 и 2+940 with noise protection barriers

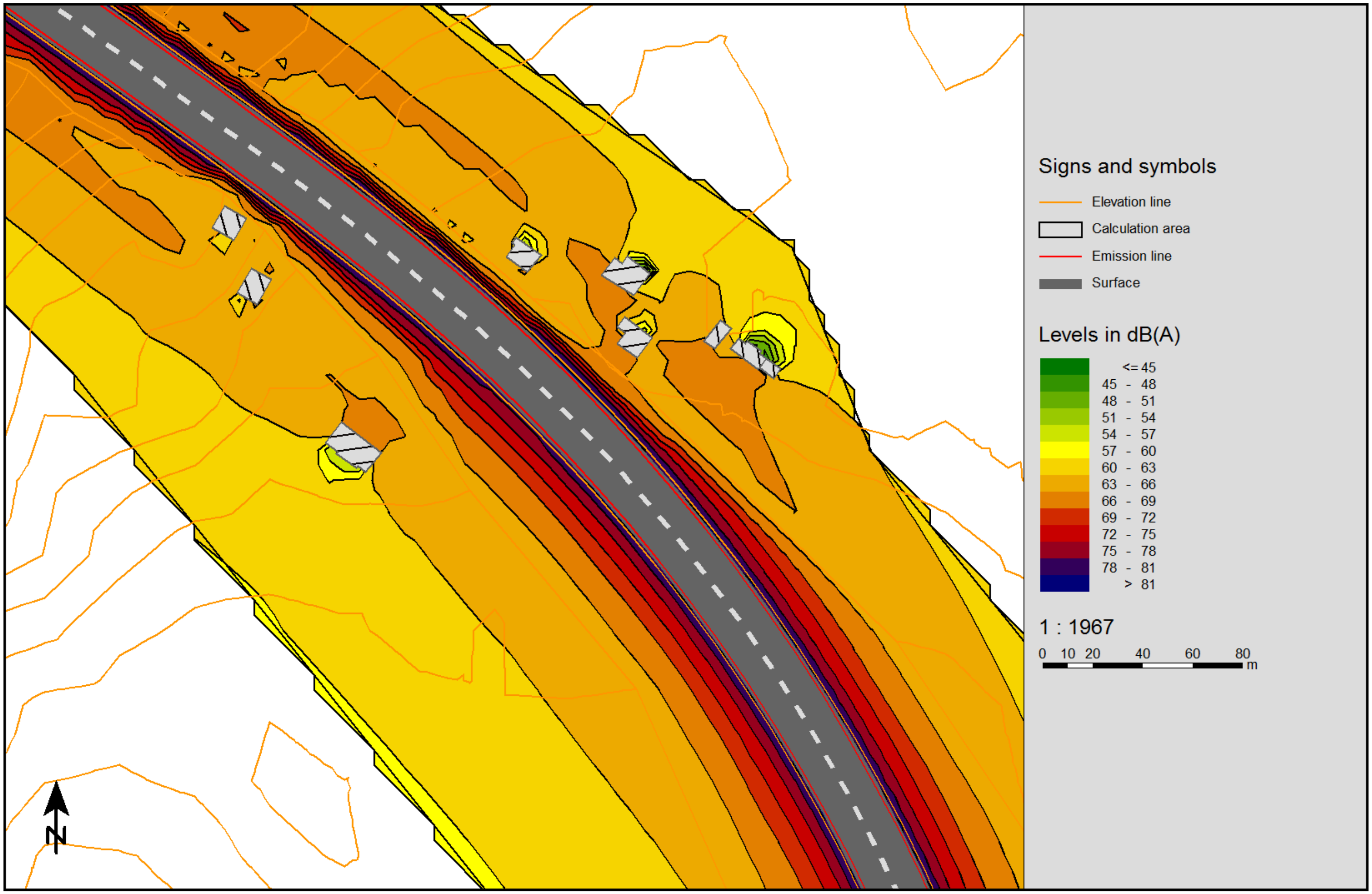

Figure 6 Groundlevel noise map (Ld) between stationing 2+780 and 2+940 without noise barriers

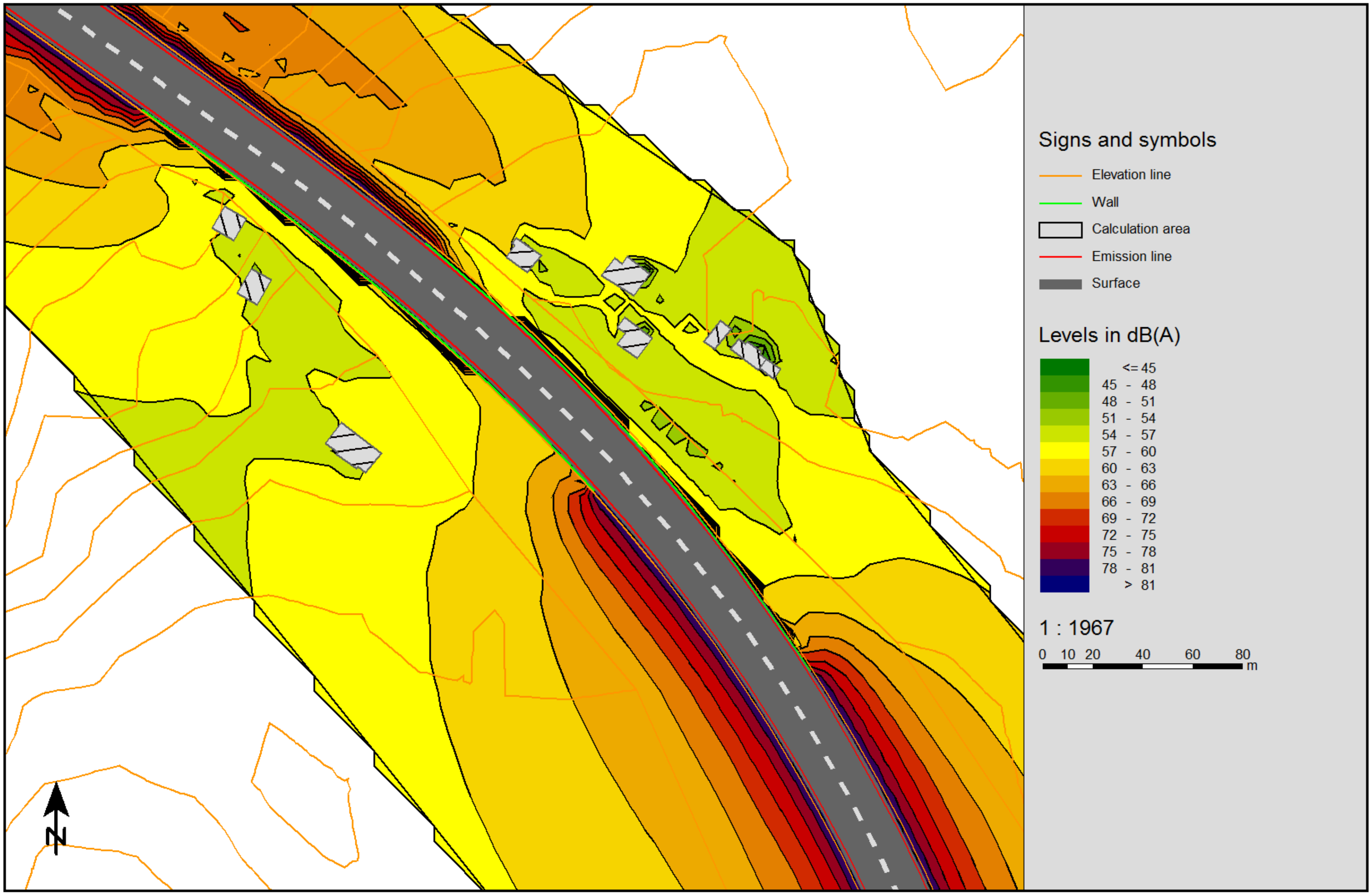

Figure 7 Groundlevel noise map (Ld) between stationing 2+780 and 2+940 with noise barriers

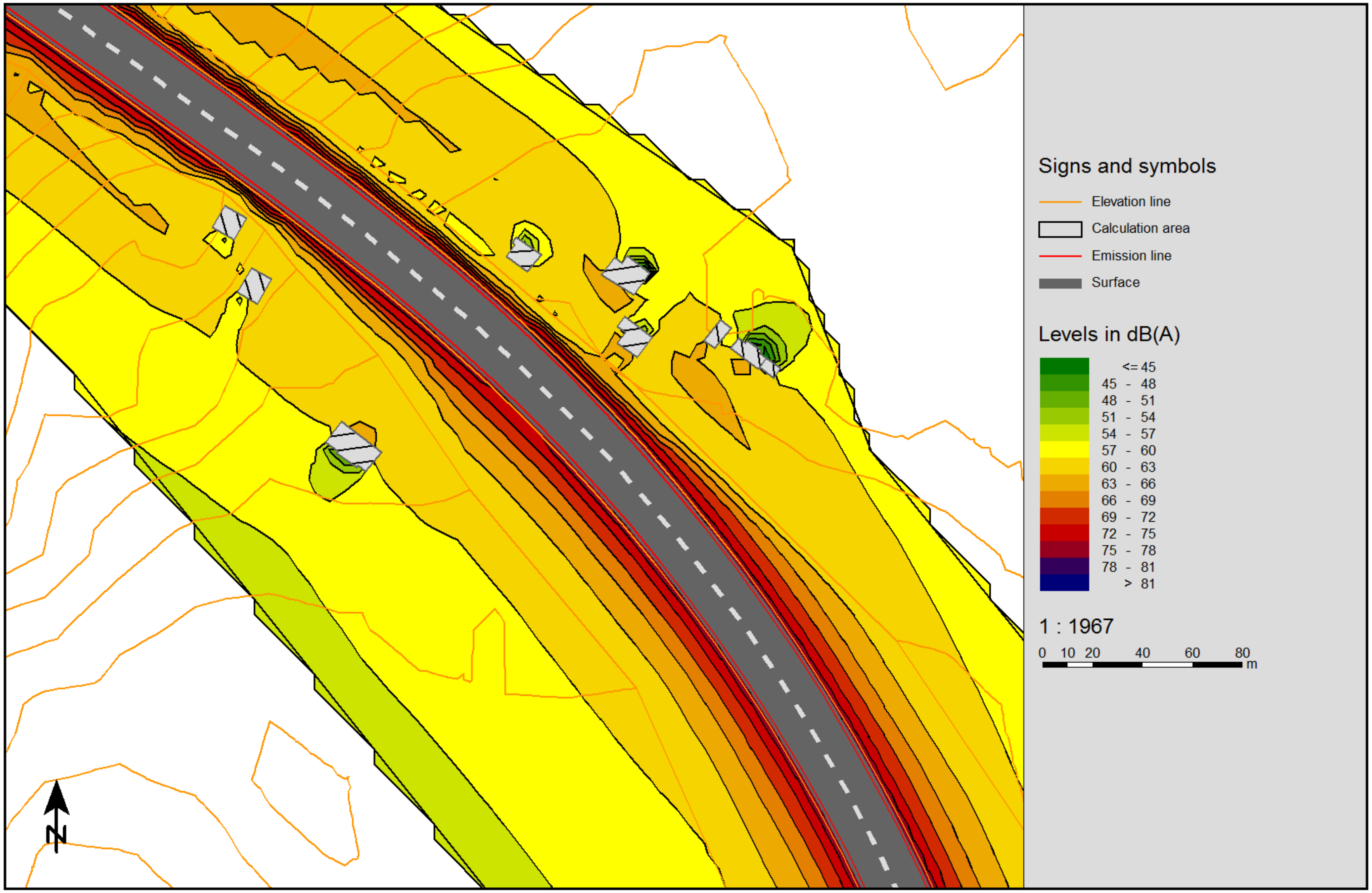

Figure 8 Groundlevel noise map (Le) between stationing 2+780 and 2+940 without noise barriers

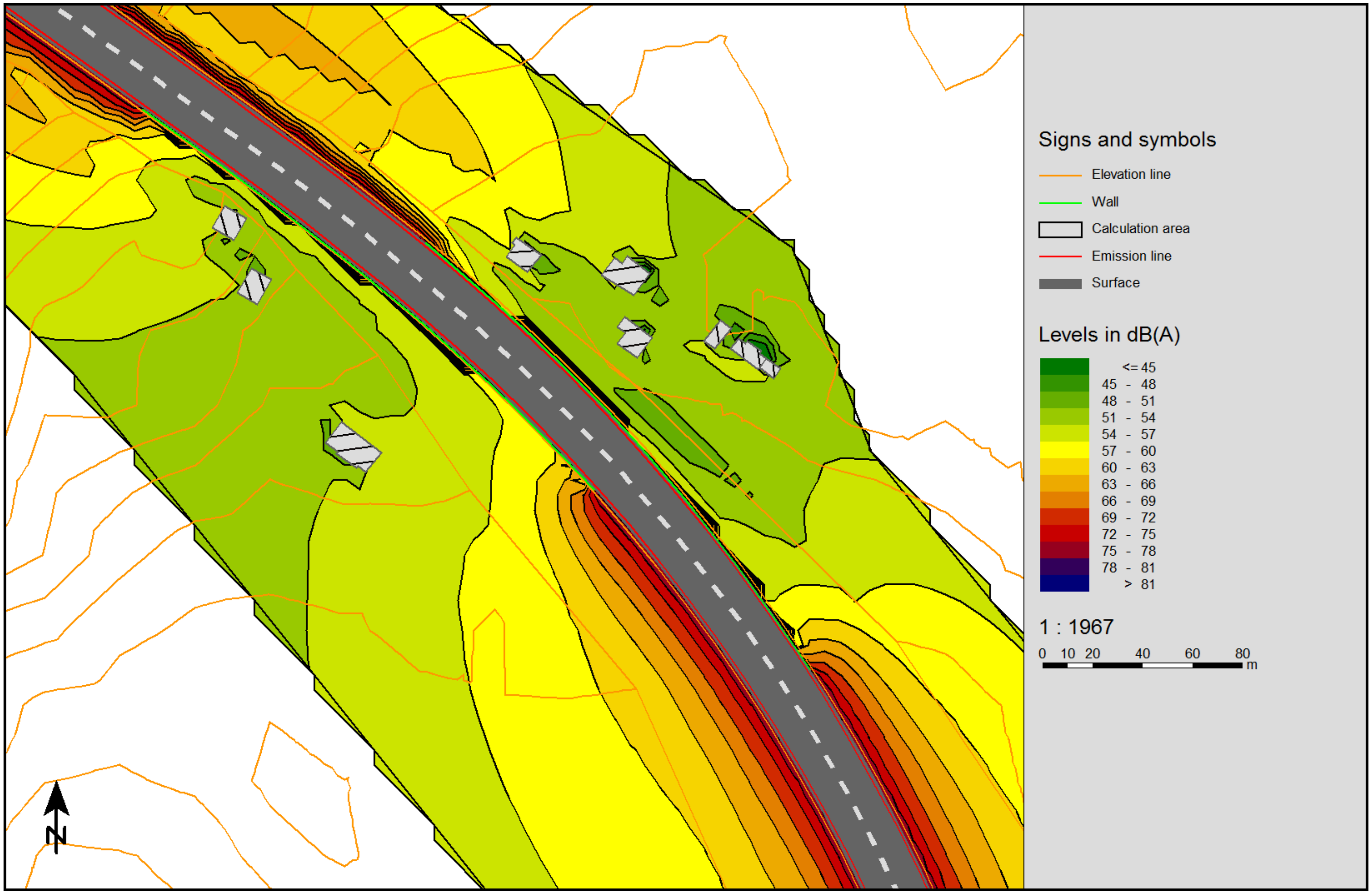

Figure 9 Groundlevel noise map (Le) between stationing 2+780 and 2+940 with noise barriers

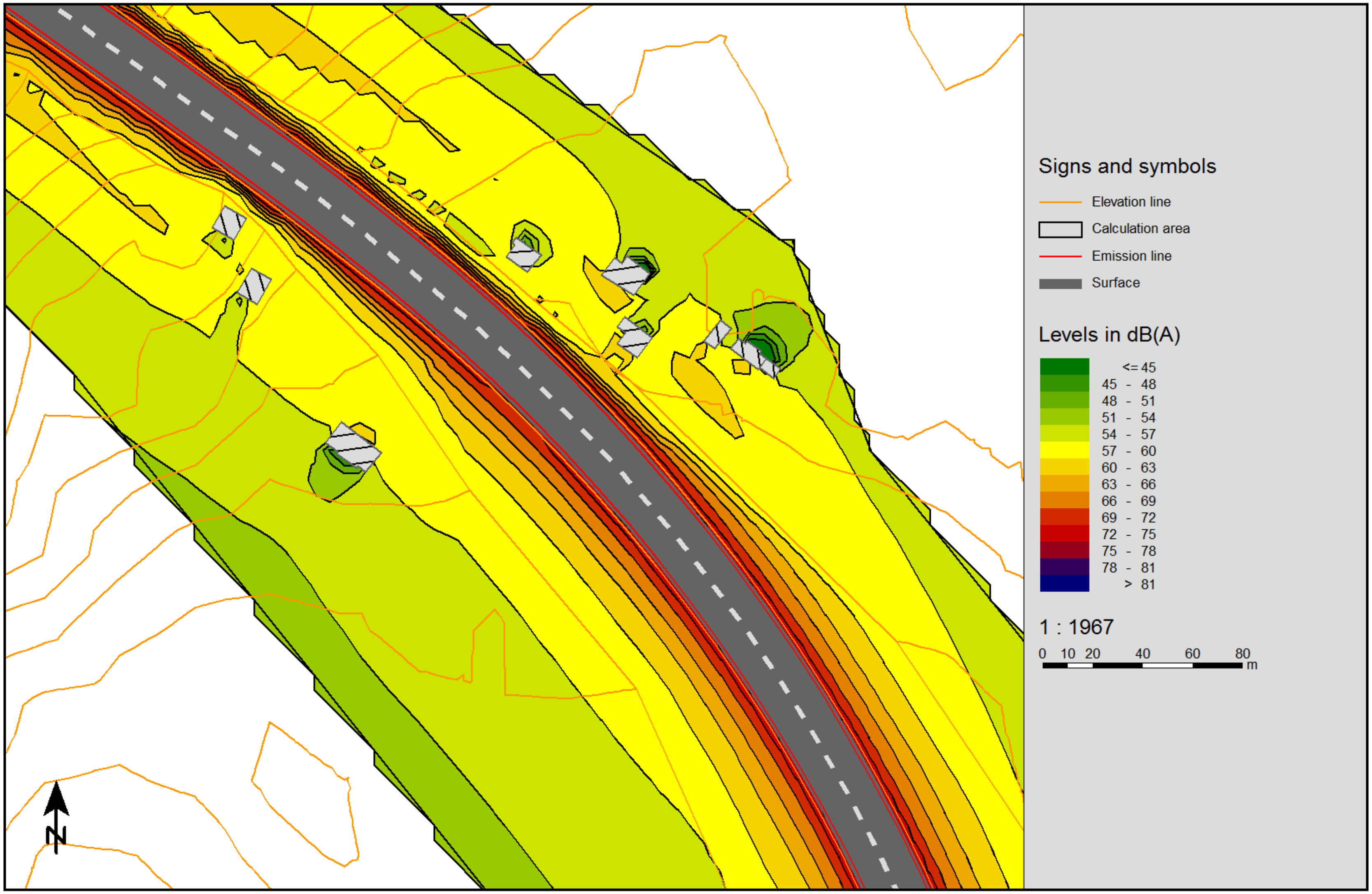

Figure 10 Groundlevel noise map (Ln) between stationing 2+780 and 2+940 without noise barriers

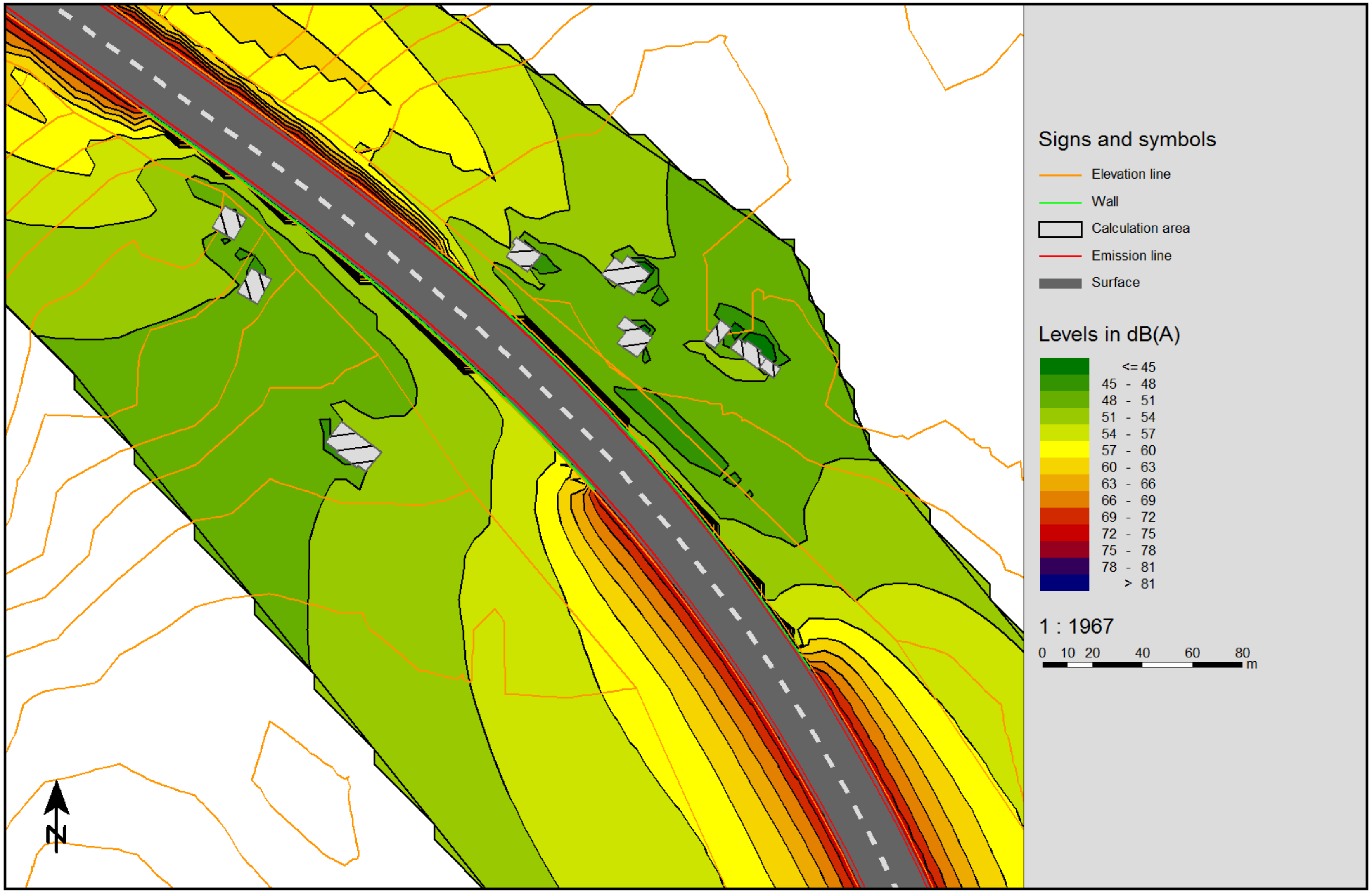

Figure 11 Groundlevel noise map (Ln) between stationing 2+780 and 2+940 with noise barriers

Table 14 Noise at sensitive receptors (Sound Plan Essential calculation) along the highway between stationing 11+243 and 12+051

	Coordinates			Limit			Level w/o NP			Level w. NP			Difference			Conflict		
No.	X	Y	Floor	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
	in meter			dB(A)			dB(A)			dB(A)			dB(A)			dB(A)		
1	7495770.8	4598863.9	GF	60	55	50	57	53.1	50.1	52.8	49	46	-4.2	-4.1	-4.1	-	-	-
2	7495729.4	4598846.5	GF	60	55	50	65.2	61.3	58.3	54.8	50.9	47.9	-10.4	-10.4	-10.4	-	-	-
3	7495750.6	4598814.2	GF	60	55	50	60.9	57.1	54	50.3	46.4	43.4	-10.6	-10.7	-10.6	-	-	-
4	7495748.9	4598755.6	GF	60	55	50	59.6	55.7	52.7	55.1	51.3	48.3	-4.5	-4.4	-4.4	-	-	-
5	7495744.4	4598861.5	GF	60	55	50	62.9	59	56	56.6	52.7	49.7	-6.3	-6.3	-6.3	-	-	-
6	7495516.5	4598450.3	GF	60	55	50	65.4	61.9	58.9	59	56.1	53.1	-6.4	-5.8	-5.8	-	1.1	3.1
7	7495558.2	4598560.0	GF	60	55	50	63.8	60	57	54.4	50.6	47.6	-9.4	-9.4	-9.4	-	-	-
8	7495729.4	4598846.5	1.Fl	60	55	50	72.4	68.5	65.5	60.4	56.5	53.5	-12	-12	-12	0.4	1.5	3.5
9	7495635.6	4598440.4	GF	60	55	50	56.3	53.3	50.3	51.7	48	45	-4.6	-5.3	-5.3	-	-	-
10	7495605.1	4598368.8	GF	60	55	50	62.9	60.1	57.1	48.5	45.1	42.1	-14.4	-15	-15	-	-	-
11	7495576.1	4598387.3	GF	60	55	50	68.9	66.2	63.2	49.1	45.9	42.9	-19.8	-20.3	-20.3	-	-	-
12	7495575.2	4598580.1	GF	60	55	50	62.7	58.9	55.9	55.3	51.5	48.5	-7.4	-7.4	-7.4	-	-	-
13	7495542.2	4598510.0	GF	60	55	50	65.5	61.7	58.7	55.6	52.1	49	-9.9	-9.6	-9.7	-	-	-
14	7495612.5	4598524.3	GF	60	55	50	55.6	51.8	48.8	55.5	51.7	48.7	-0.1	-0.1	-0.1	-	-	-
15	7495578.1	4598415.4	GF	60	55	50	65.1	62.3	59.3	52.8	49.3	46.2	-12.3	-13	-13.1	-	-	-

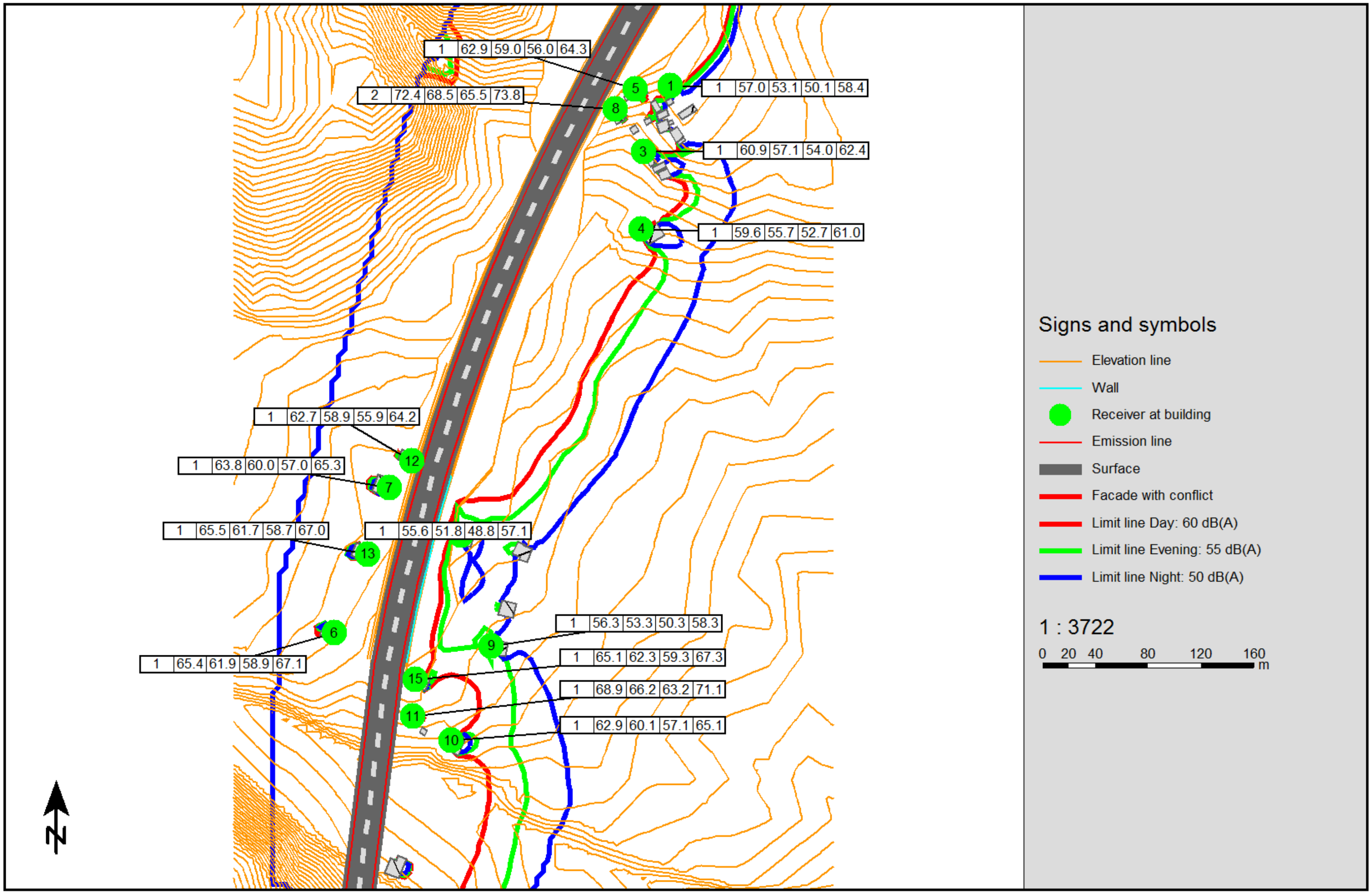

Figure 12 Single point noise levels between stationing 11+243 и 12+051 without noise protection barriers

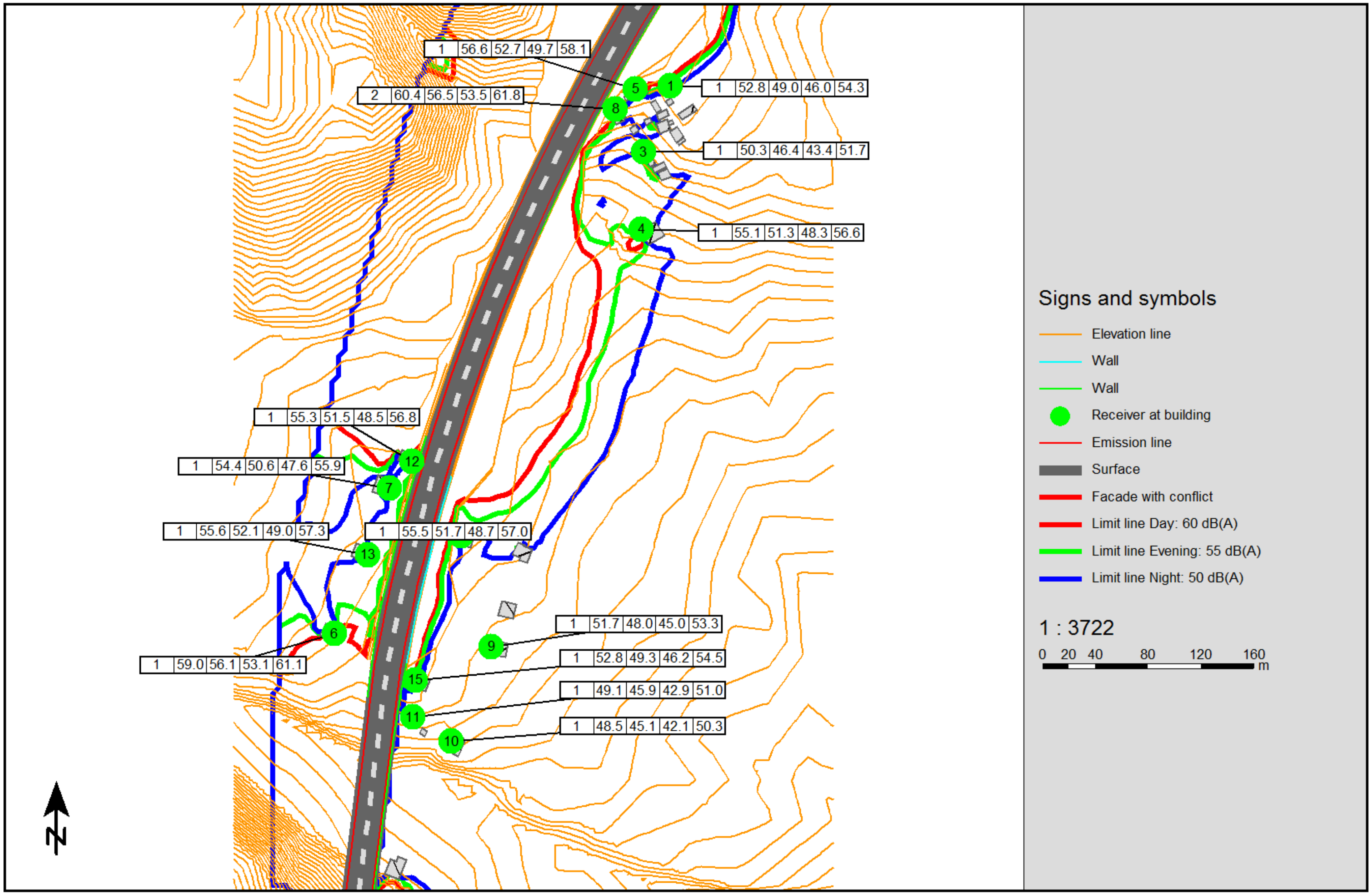

Figure 13 Single point noise levels between stationing 11+243 и 12+051 with noise protection barriers

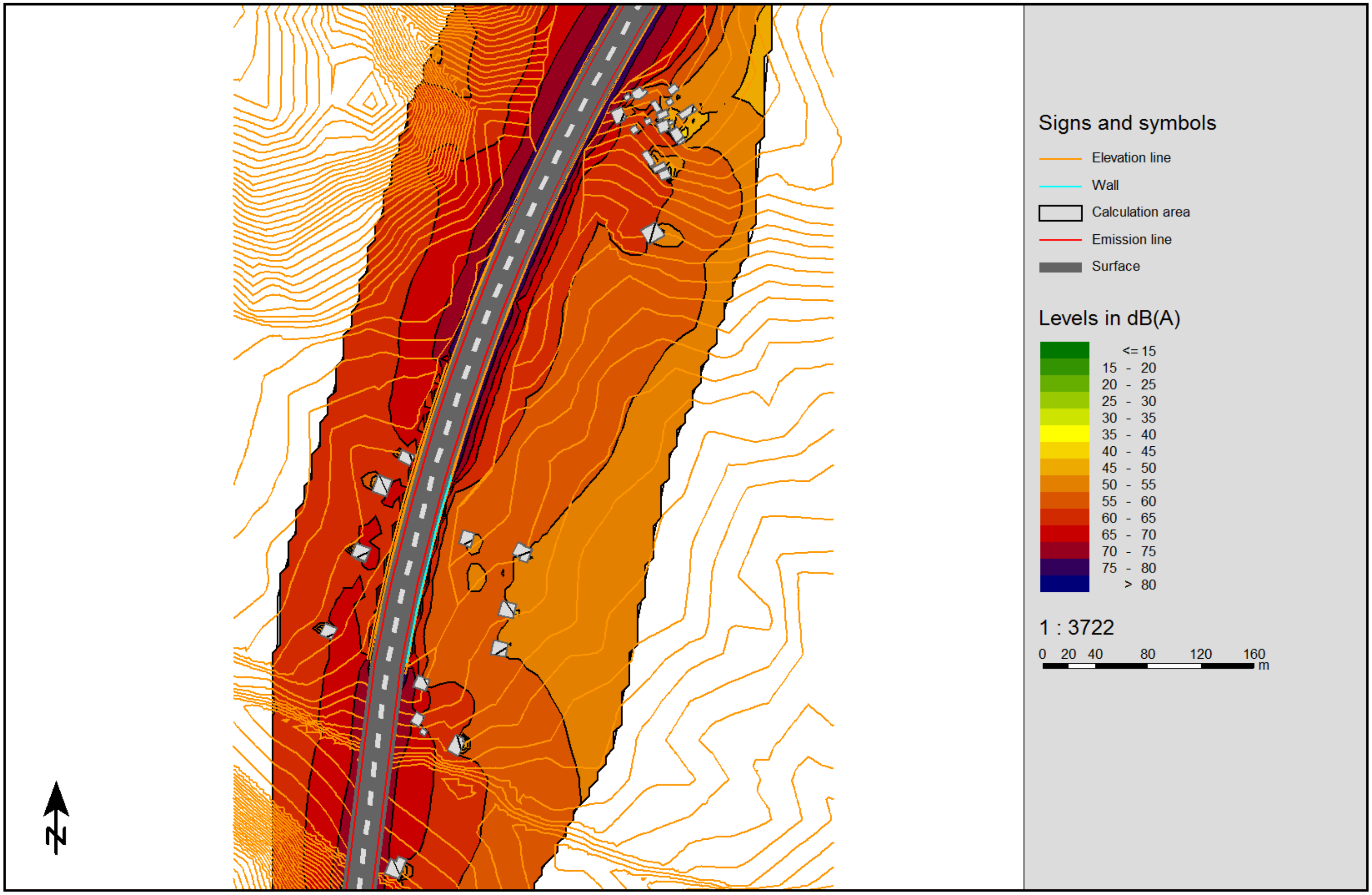

Figure 14 Ground level noise map (Ld) between stationing 11+243 and 12+051 without noise barriers

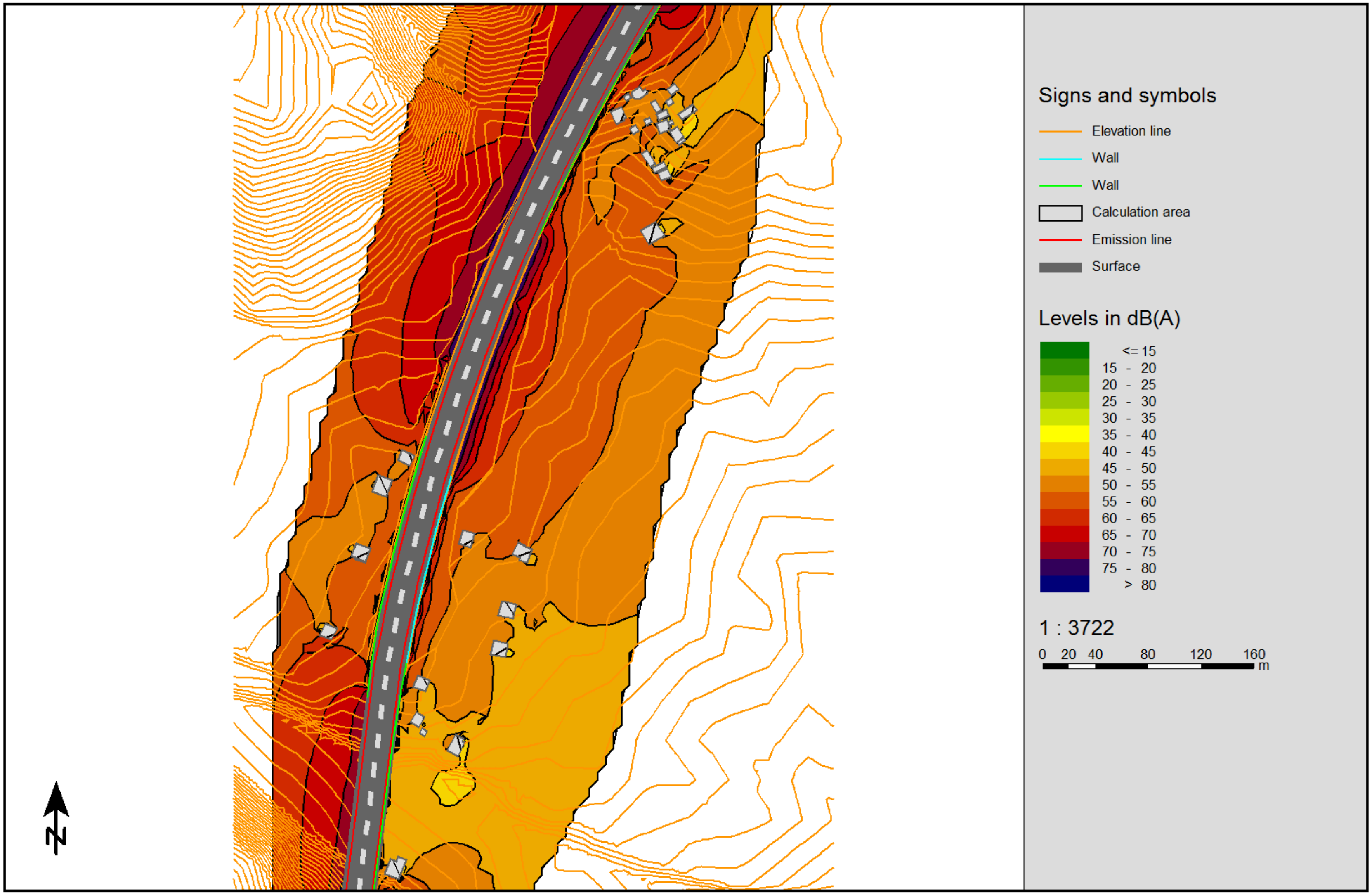

Figure 15 Groundlevel noise map (Ld) between stationing 11+243 and 12+051 with noise barriers

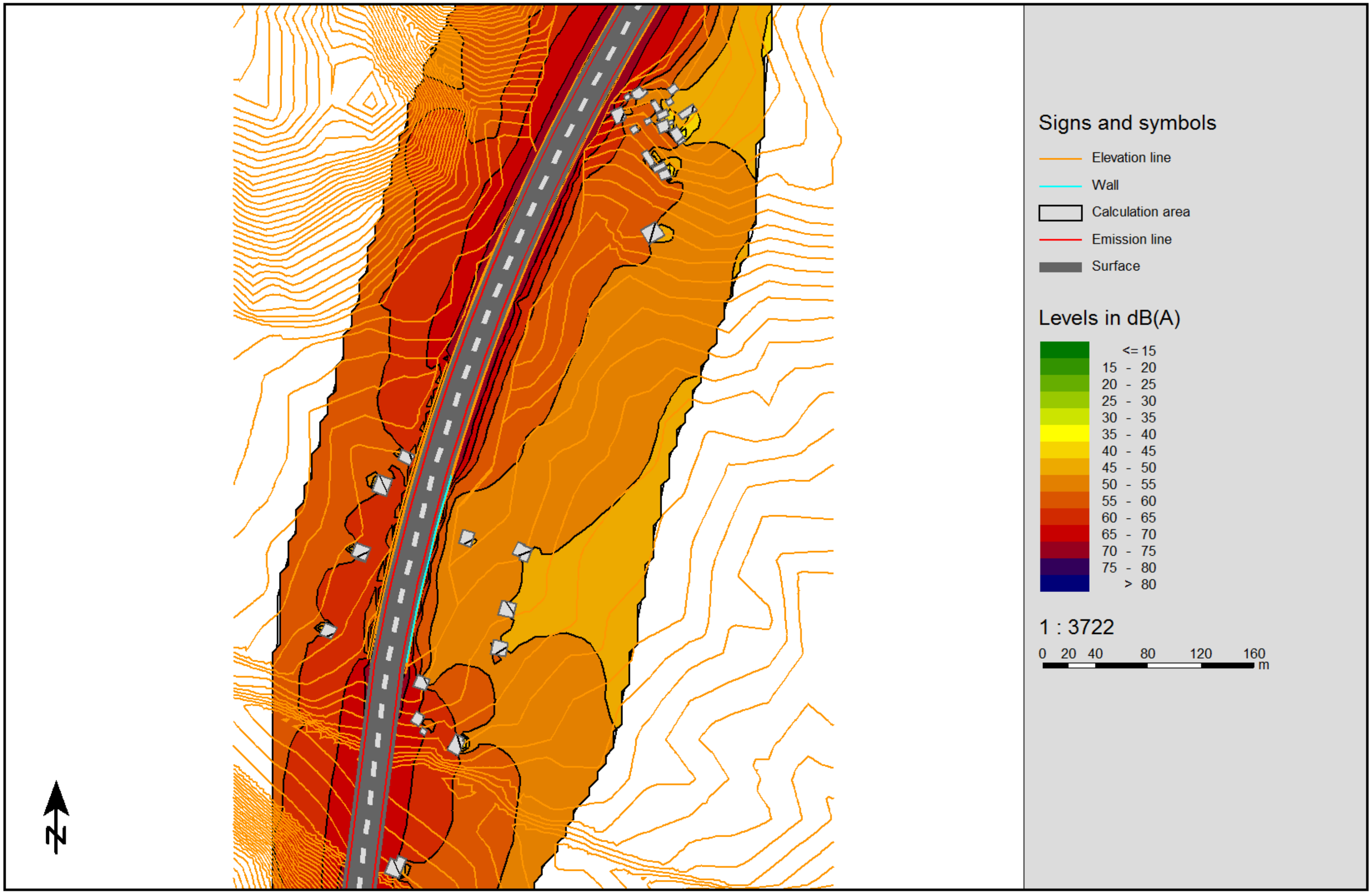

Figure 16 Groundlevel noise map (Le) between stationing 11+243 and 12+051 without noise barriers

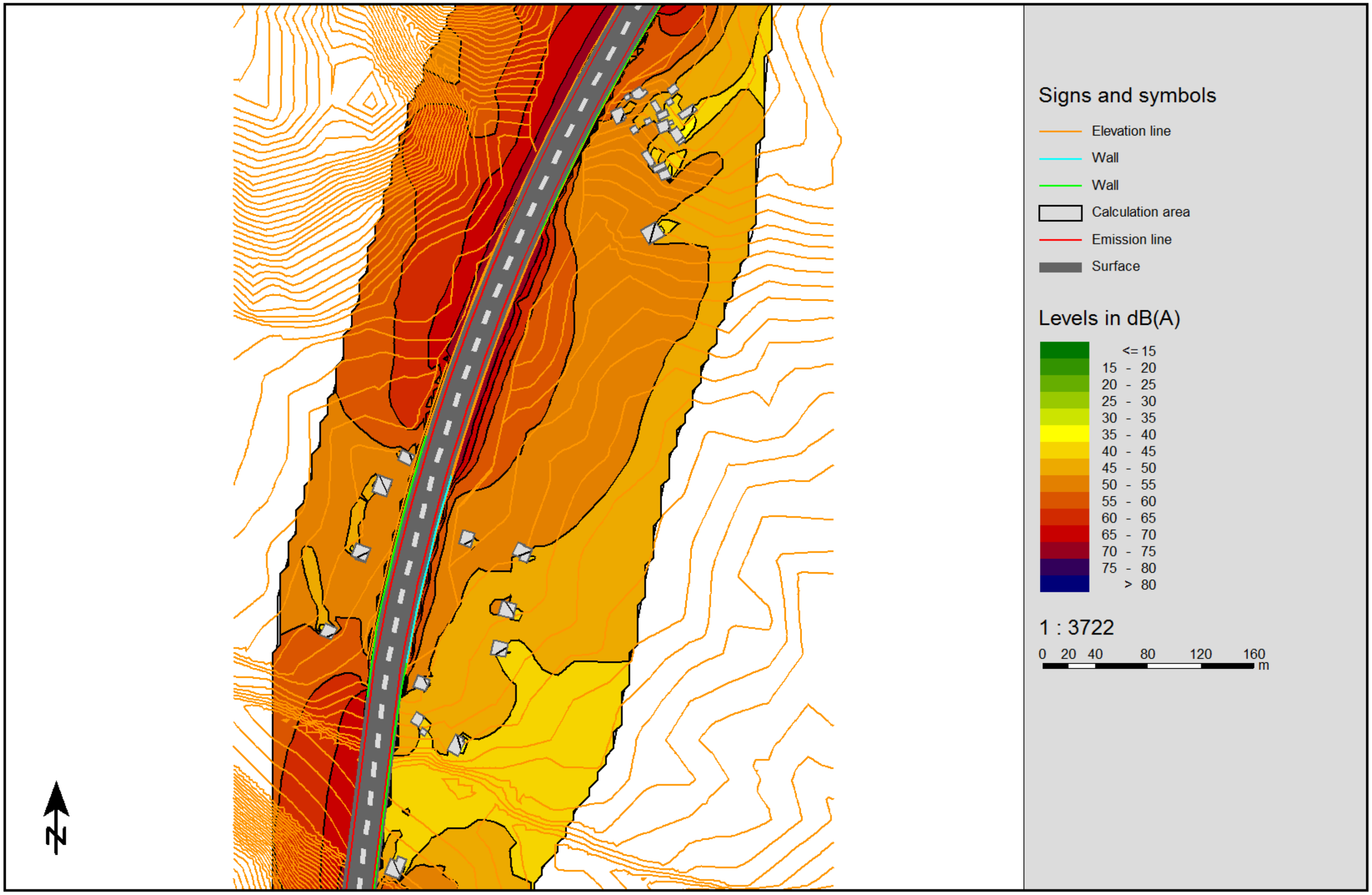

Figure 17 Groundlevel noise map (Le) between stationing 11+243 and 12+051 with noise barriers

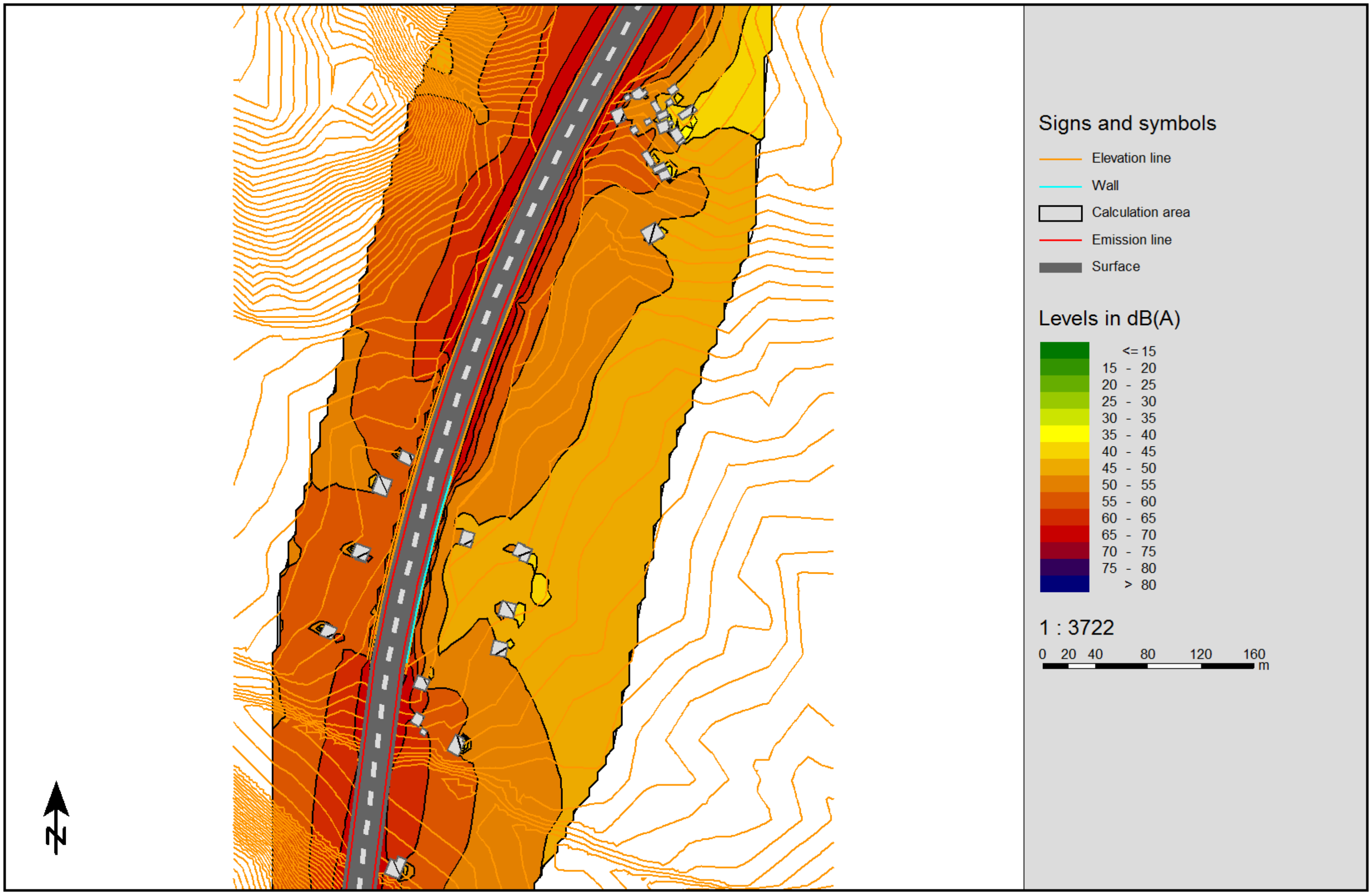

Figure 18 Groundlevel noise map (Ln) between stationing 11+243 and 12+051 without noise barriers

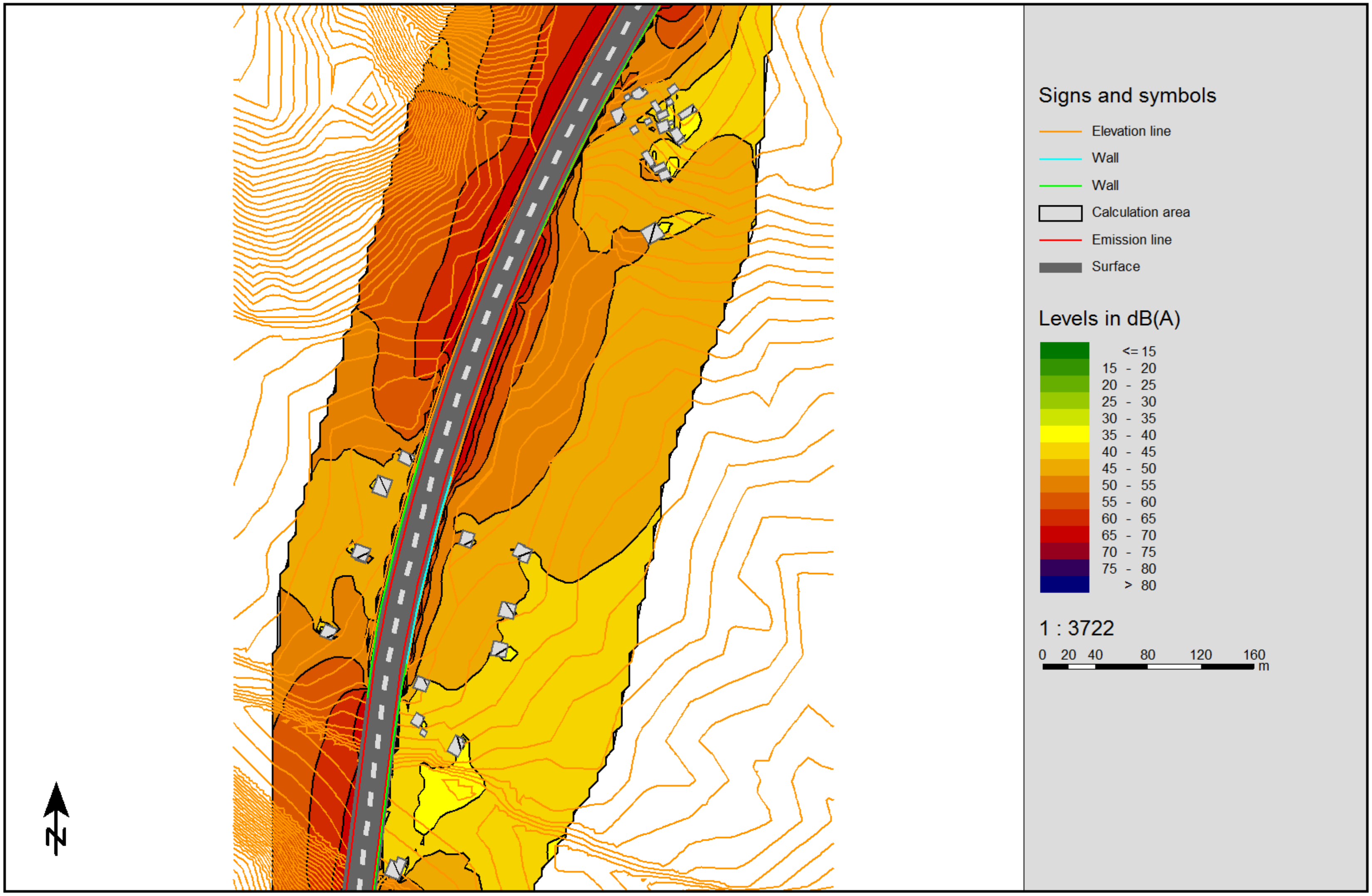

Figure 19 Groundlevel noise map (Ln) between stationing 11+243 and 12+051 with noise barriers

Figure 20 Noise at sensitive receptors (Sound Plan Essential calculation) along the highway between stationing 12+412 and 12+542

No.	Receiver	Building	Floor	Limit			Level w/o NP			Level w. NP			Difference			Conflict			
				Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night	Lden
		side		dB(A)			dB(A)			dB(A)			dB(A)			dB(A)			
1	1	West	GF	60	55	50	68.5	64.7	61.7	47.1	43.3	40.2	-21.4	-21.4	-21.4	-	-	-	-
2	2	West	GF	60	55	50	70	66.1	63.1	46.6	42.8	39.7	-23.4	-23.4	-23.4	-	-	-	-
3	3	West	GF	60	55	50	63.5	59.7	56.7	44.6	40.7	37.7	-18.9	-18.9	-18.9	-	-	-	-
4	4	West	GF	60	55	50	63.8	60	57	46.1	42.2	39.2	-17.7	-17.7	-17.7	-	-	-	-
5	5	West	GF	60	55	50	62.2	58.3	55.3	45.5	41.6	38.6	-16.7	-16.7	-16.7	-	-	-	-
5	5	West	1.Fl	60	55	50	64.1	60.2	57.2	46.4	42.5	39.5	-17.7	-17.7	-17.7	-	-	-	-

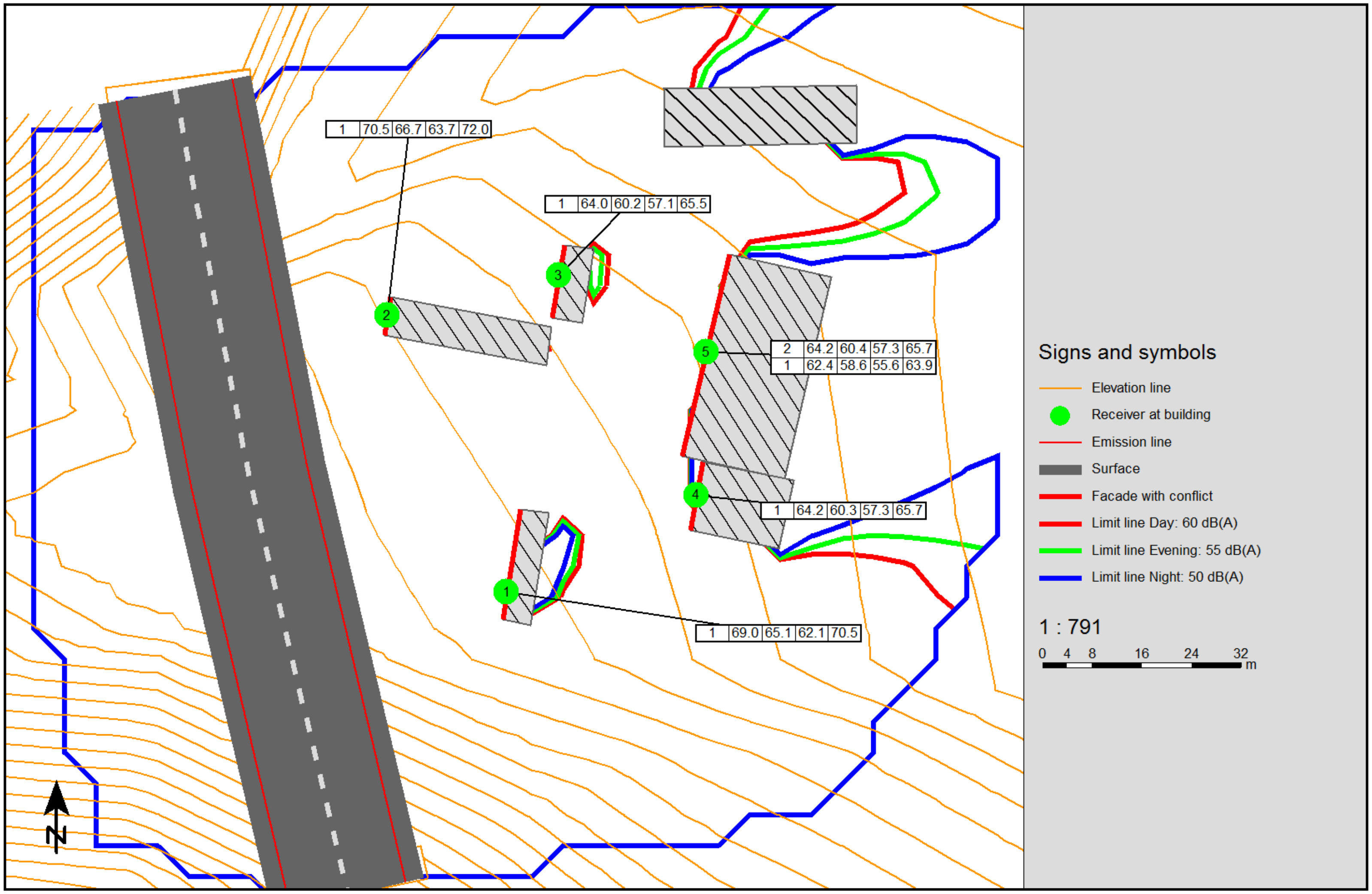

Figure 21 Single point noise levels between stationing 12+412 and 12+542 without noise protection barriers

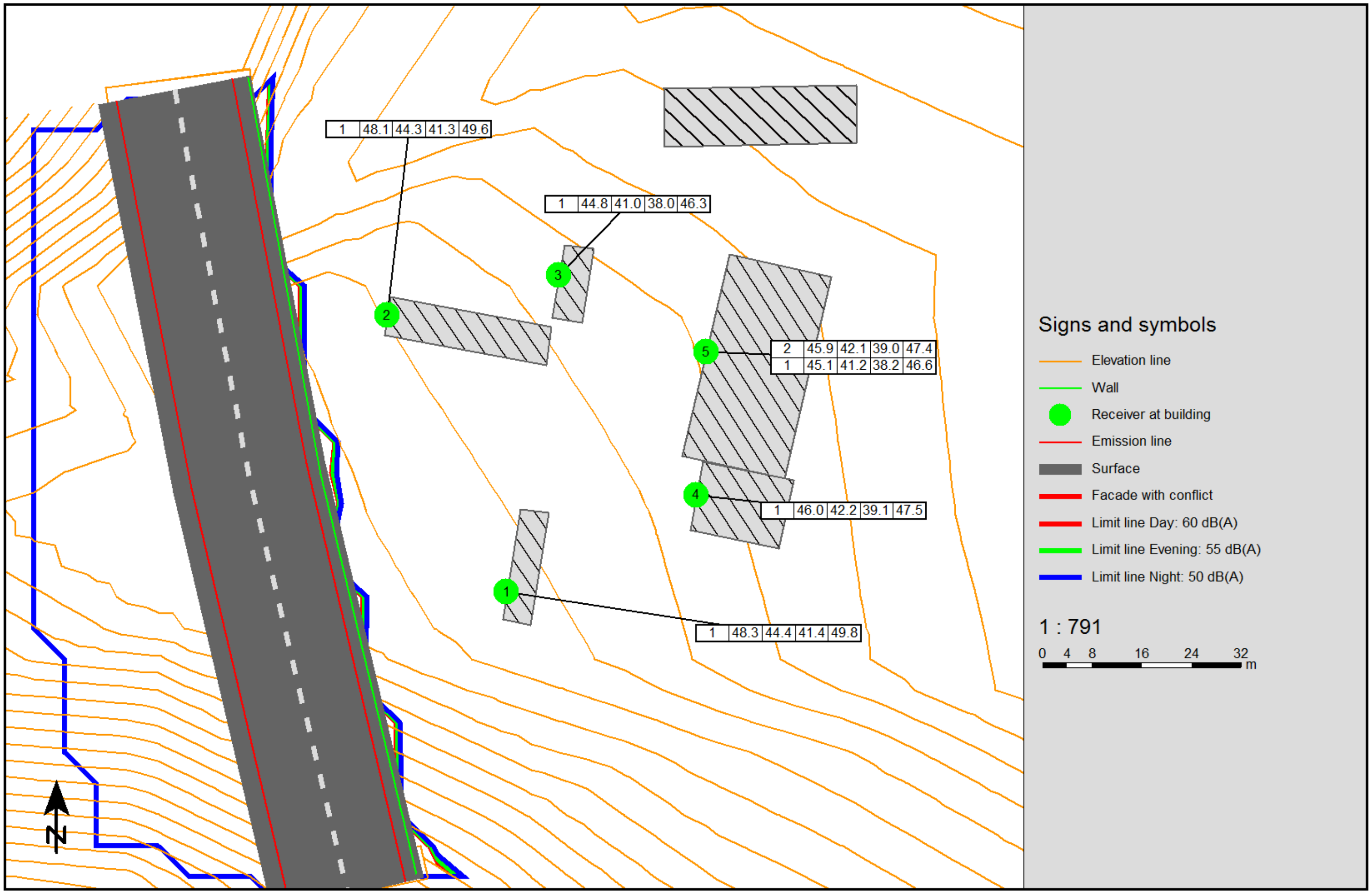

Figure 22 Single point noise levels between stationing 12+412 and 12+542 withnoise protection barriers

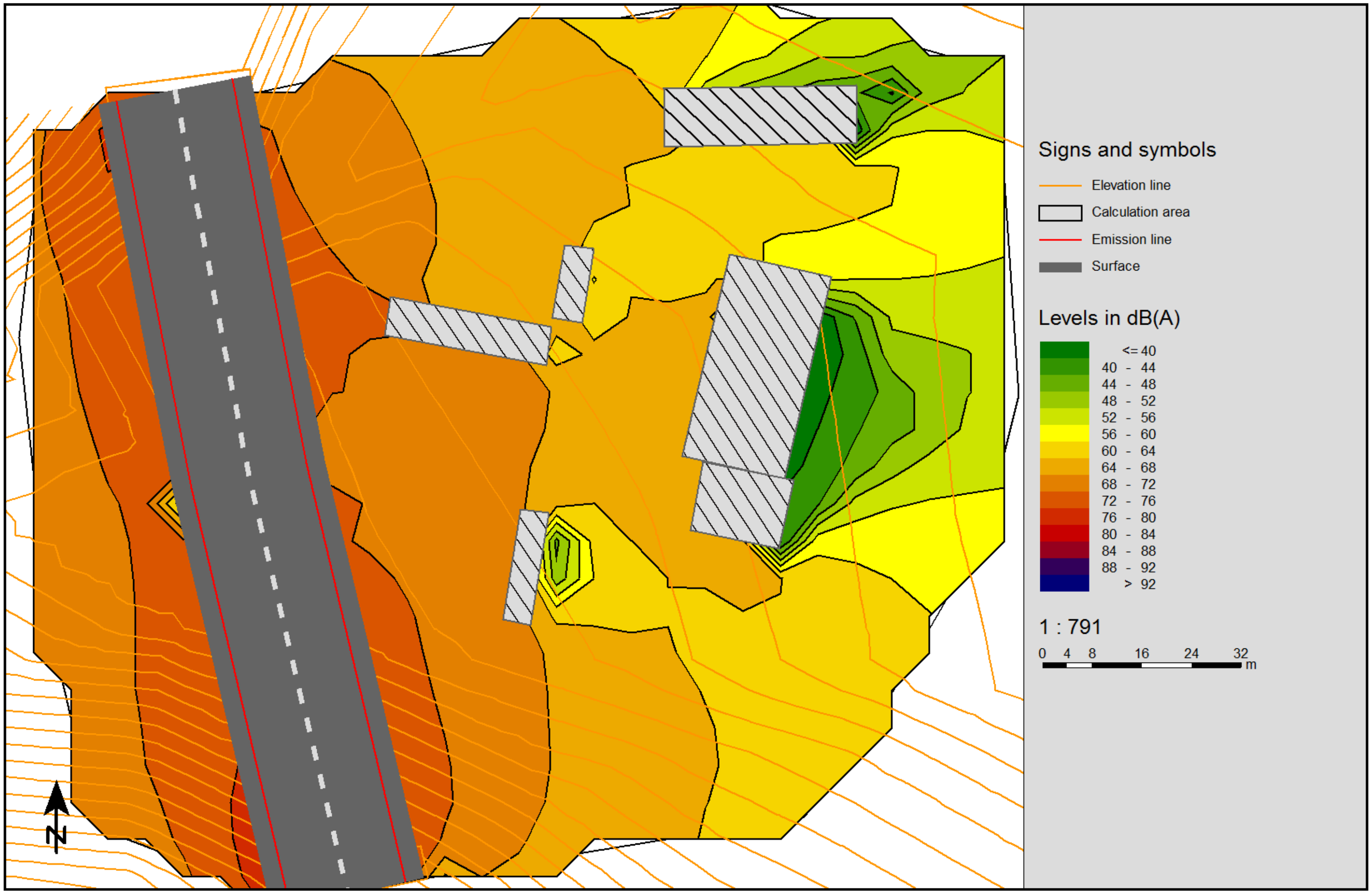

Figure 23 Ground level noise map (Ld) between stationing 12+412 and 12+542 without noise barriers

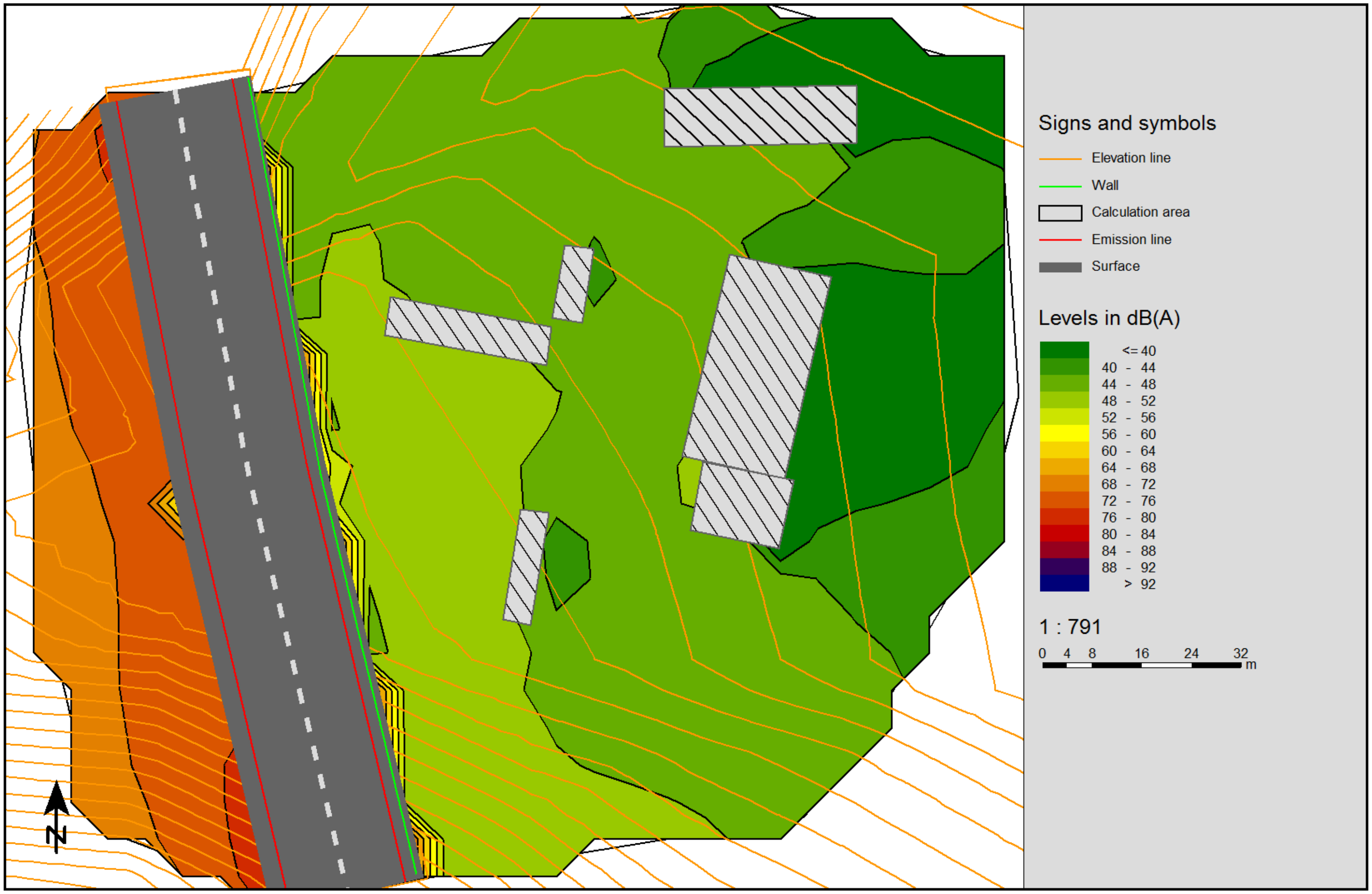

Figure 24 Ground level noise map (Ld) between stationing 12+412 and 12+542 with noise barriers

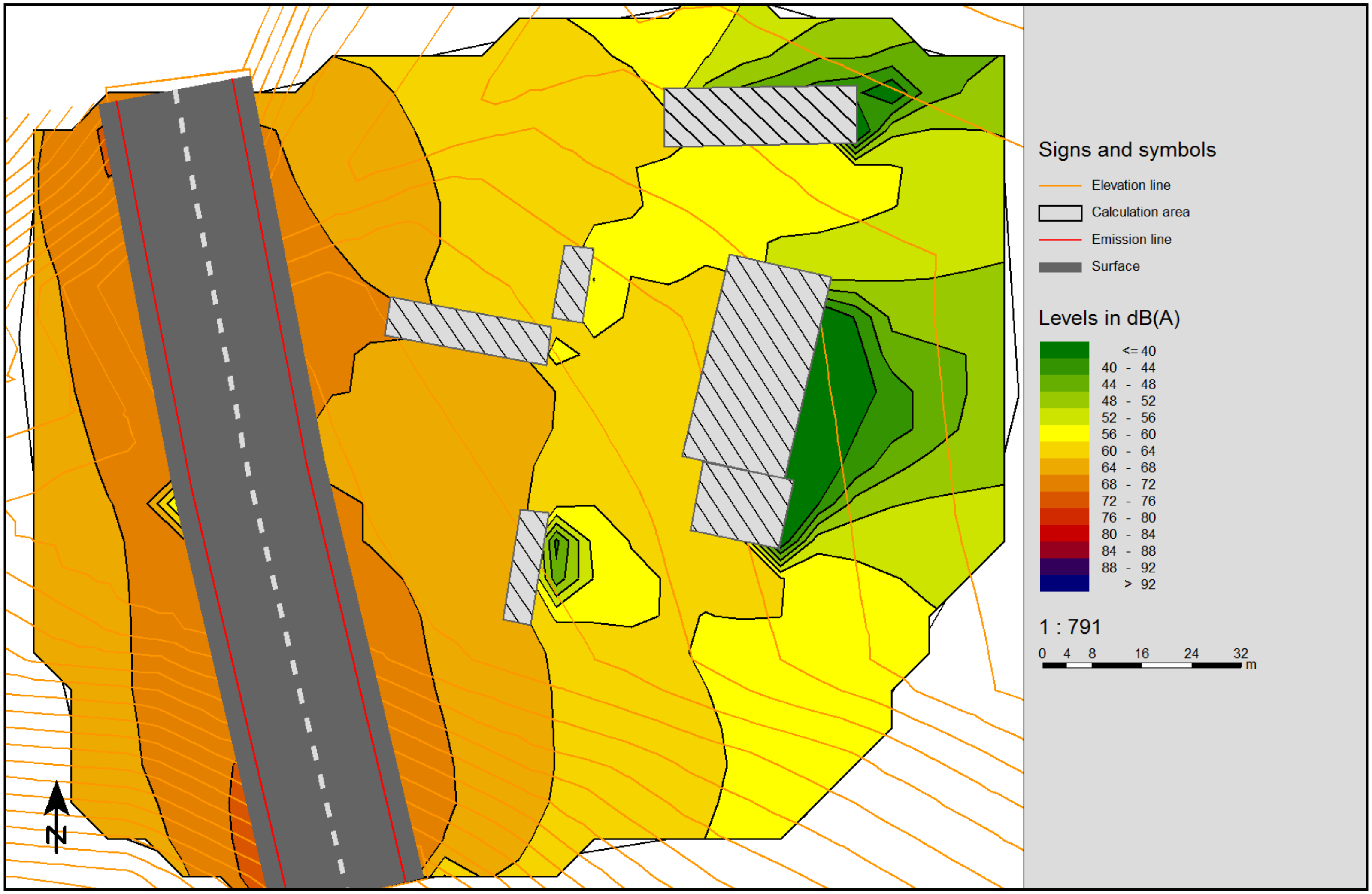

Figure 25 Ground level noise map (Le) between stationing 12+412 and 12+542 without noise barriers

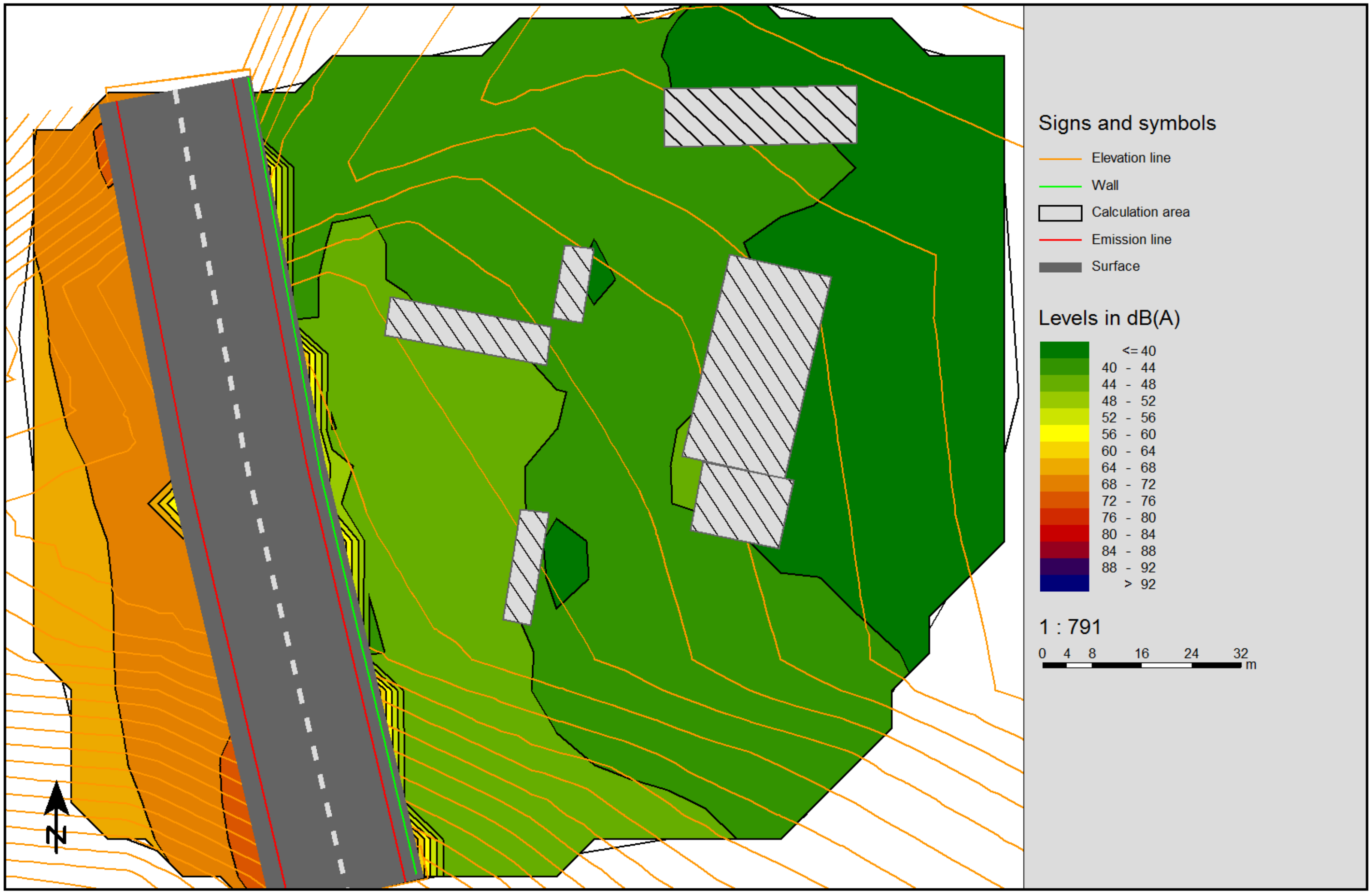

Figure 26 Ground level noise map (Le) between stationing 12+412 and 12+542 with noise barriers

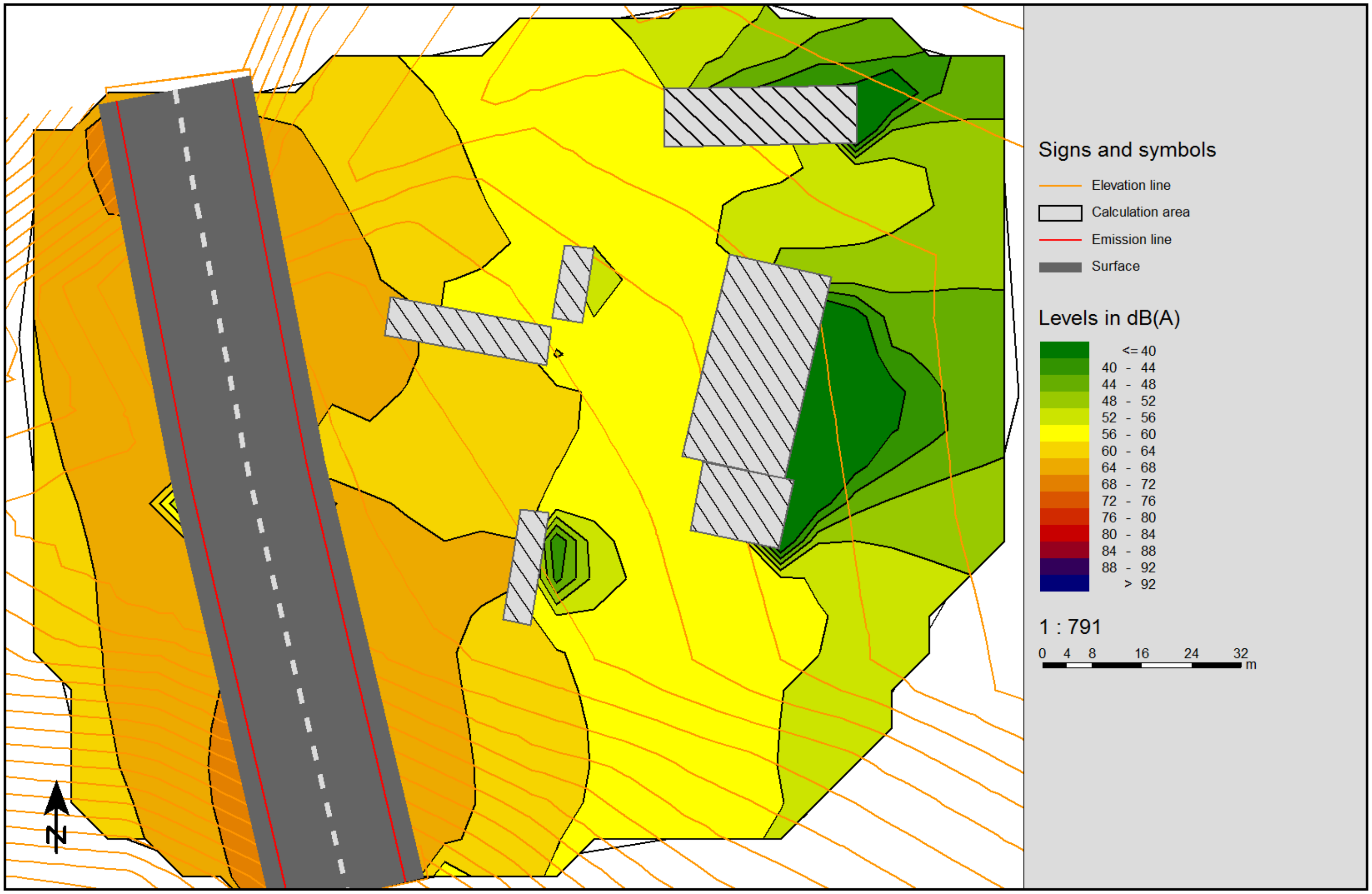

Figure 27 Ground level noise map (Ln) between stationing 12+412 and 12+542 without noise barriers

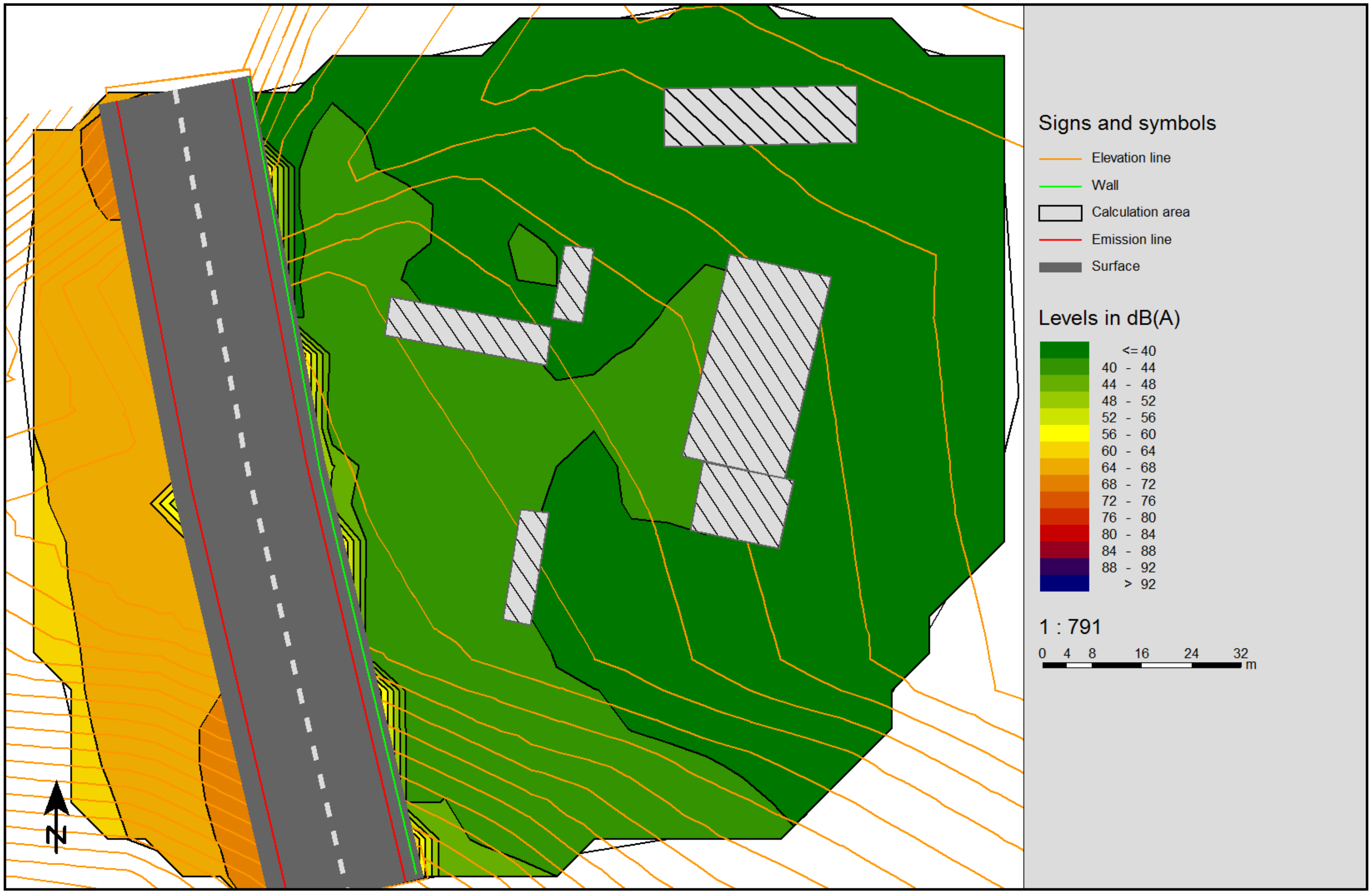

Figure 28 Ground level noise map (Ln) between stationing 12+412 and 12+542 with noise barriers