NOISE REPORT

ODOT Solar Highway Project: West Linn Site
Clackamas County

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Oregon Department of Transportation
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1.0 Summary

This report analyzes the potential changes in noise levels resulting from the proposed Solar Highway Project in West Linn, Oregon. The project will place solar arrays and inverters on the north side of I-205 to generate approximately 3,000,000 kilowatt-hours of renewable energy to power the Oregon transportation system. The project will place between 13,000 and 17,000 panels and ten 260 kilowatt (kW) inverters at the site. Solar inverters will be clustered at 3 separate locations with 3 to 4 inverters at each location for a total of 10 inverters.

Changes to the noise environment which is dominated by the traffic noise from I-205, due to either the noise emitted from the solar inverters or as a result of on-site tree removal are analyzed in this report as part of the National Environmental Policy Act (NEPA) process. The conservative analysis determined that during the day the solar inverters will increase noise levels at residential receivers (receiver) by 2 dBA or less and that this change will not be perceptible to human ears[1]. However, in spring and summer, during the 1st hour and last two hours of daylight when traffic noise is reduced, solar inverters may increase noise levels at the closest residences by 3 dBA or less. This change is just perceptible to human ears. At night, the inverters will not emit any sound. The effects of tree removal on the project site will not cause clearly noticeable changes in noise levels (5 dBA). The trees slated for removal are not currently dense or tall enough to provide shielding for the residences located along the northern edge of the right-of-way (ROW) from I-205 traffic noise.

Once the project is in place, additional noise monitoring will be conducted to determine if mitigation needs to be considered.

2.0 Background

2.1 Project Site and Surroundings

The Solar Highway project will be located within ODOT right-of-way (ROW), on the north side of I-205, in the south portion of the City of West Linn. The site contains 3 geological benches, carved into the bedrock to stabilize the slope and protect the highway. The benches increase in elevation from I-205, as you go north, with the 3rd bench, located at the northern edge of the ROW, being the highest. The first and second benches will be used for placement of the solar inverters and arrays. The areas adjacent to the project include single-family residences to the north and industrial and commercial properties to the south of I-205. Figure 1 shows the Vicinity Map.

[1] The findings of this report are specific to the inverter locations and inverter groupings examined in this report.

2.2 Applicable Regulations

Noise impacts from highway transportation projects are regulated by 23 CFR 772, however, for this project there are no changes to the number of lanes or the vertical or horizontal roadway alignment or traffic volumes, distributions, or speeds; therefore, 23 CFR 772 is not applicable to this project.

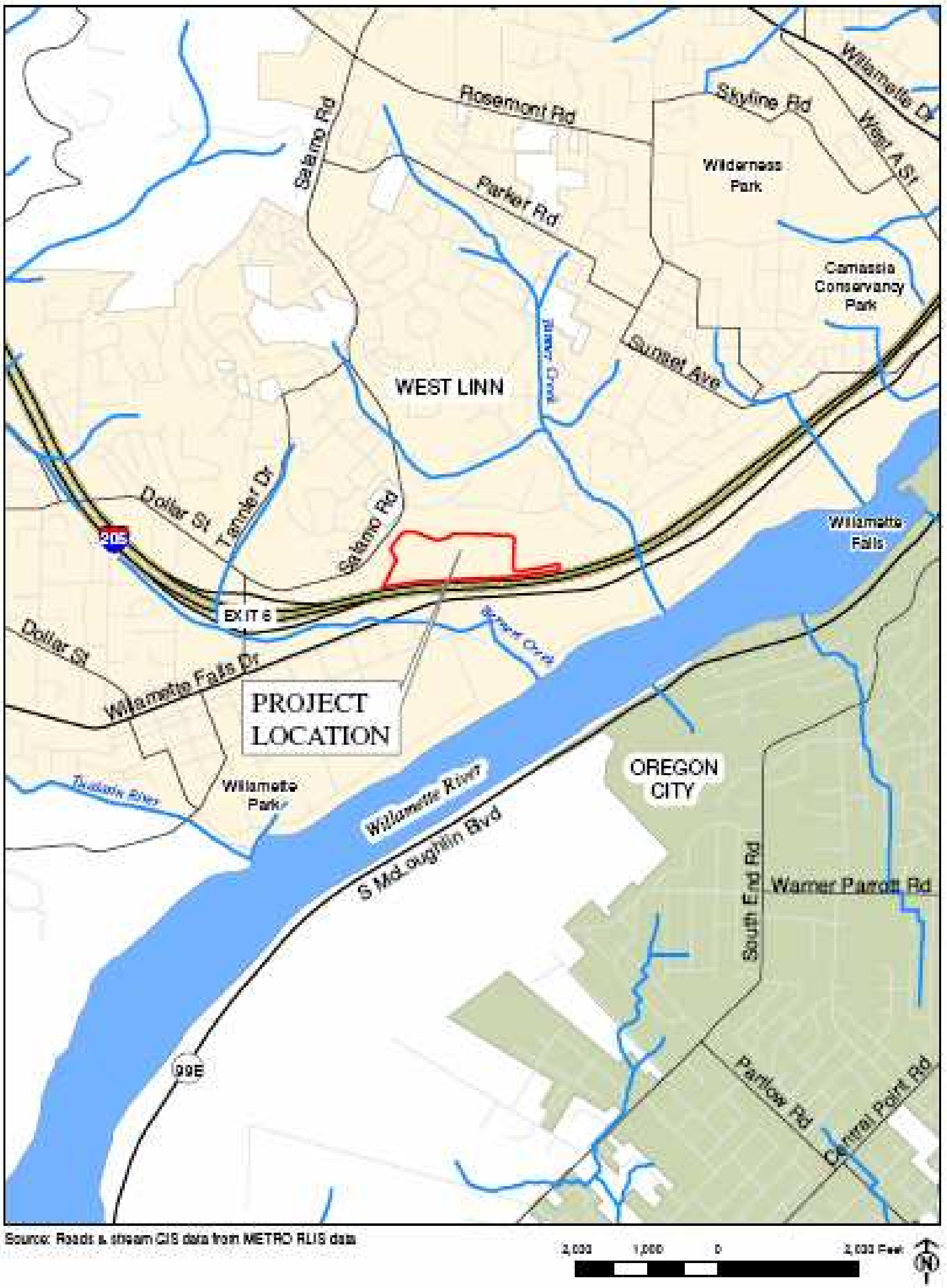


FIGURE 1.
Vicinity Map

The Oregon Revised Statues (ORS Chapter 467) Noise Control and Oregon Administrative Rules (OAR Division 35) Noise Control Regulations were reviewed for applicability. Although the site is unzoned highway ROW and currently not classified as industrial use, the project could be considered a new industrial/commercial noise source and thus subject to state noise regulations (OAR 340-035-0035). The total noise level contributed from this new source is summarized in the results tables and compared to the applicable noise standard (Table 9).

The National Environmental Policy Act (NEPA) requires that the environmental impacts from federally funded projects be evaluated and therefore the change in noise levels for the project with solar inverters will be evaluated. Because the site is unzoned highway right-of-way, the City of West Linn's noise zoning codes are not applicable. The City staff requested that the Noise Report for the West Linn Solar Highway Project include a discussion of potential changes to the noise levels resulting from tree removal. The City also requested that ODOT provide a comparison of ambient noise levels to new noise levels with inverter noise contribution to determine if there would be an increase in noise levels.

2.3 Background on Noise

Sound is composed of pressure waves within the atmosphere. The human ear can detect some of these atmospheric disturbances. A logarithmic scale, the decibel system, has been selected to describe the range of hearing from the weakest pressure wave that can be heard by a person with good hearing in very quiet surroundings to the strongest. The measurement unit is the decibel (dB). The equation for this descriptor is:

$$\text{decibel} = 10 \log \left(\frac{\text{Pressure}}{0.00002 \text{ Newton per square meter}}\right)^2$$

Using this scale, the weakest sound which can be heard (0.00002 N/m^2) is 0 dB. The pressure creating pain (about 200 N/m^2) is about 140 dB.

The "A-scale" is a frequency weighting system which closely represents the average human hearing response. It has become the most widely accepted frequency system today. A sound level adjusted with this system is called decibels "A-weighted" or dBA. Table 1 shows how the change in dBA is perceived by the human ear.

Sound levels decrease as the distance from the sound source increases. The reduction rate varies with the type of source. Theoretically, a point source, like a solar inverter, has a rate described as a 6 dBA reduction per doubling of distance. A line source, such as the highway, has a 3 dBA reduction per doubling of distance. Acoustic barriers such as topography, like the large flat areas divided by steep slopes at this project site, vegetation, buildings, or walls can also reduce noise.[2]

[2] http://www.fhwa.dot.gov/environment/noise/design/index.htm

Sound levels within the environment, like traffic, often change randomly. To describe varying sound, a measurement system which averages the sound pressure levels over time is used. The Leq measurement system is the energy-averaged[3] decibel level and has been found to correlate well with human's perceptions of noise and its effects. Another noise statistical descriptor is L_{10} which represents the noise level that is exceeded 10% of the time in the noisiest hour of the day. Leq for typical traffic noise conditions is usually about 3 dBA less than L_{10} for the same traffic conditions.[4]

The addition of a point source to an existing noise environment would have a larger change in noise level for quiet (lower) noise hours compared to higher or peak noise hour. This occurs because peak noise hour will shield some of the effect of the additional noise source.

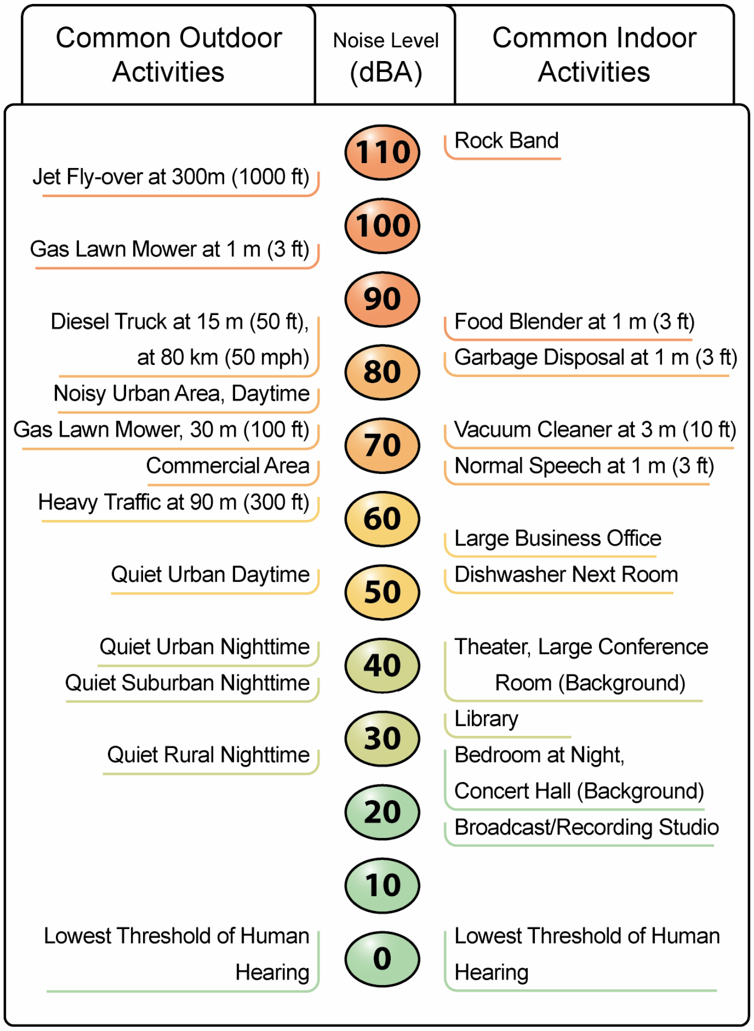
Figure 2 shows a comparison between noise levels and familiar activities.

Table 1. Perceived Change in Noise Levels

Change in Sound Level	Perceived Change to the Human Ear
+/- 1 dBA	Not Perceptible
+/- 3 dBA	Threshold of Perception
+/- 5 dBA	Clearly Noticeable
+/- 10 dBA	Twice (or Half) as Loud
+/- 20 dBA	Fourfold (4x) change

Figure 2. Noise Levels of Common Outdoor and Indoor Actitives

[3] usually hourly averages for highway noise measurements
[4] http://www.fhwa.dot.gov/environment/probresp.htm



3.0 Methodology

To analyze the change in noise levels resulting from the addition of the noise from the solar inverters, three residences (receivers, RM6, RM8 and R11) closest to each of the 3 inverter pads (I10, IM5 and IM7) were selected. The measured noise levels at the residential locations were then compared to the calculated noise levels with inverter noise contribution. The noise measurements were conducted at an off peak noise hour to represent the average noise level. Inverter noise levels, at 50 feet from the source, were supplied by the manufacturer. The inverter noise level contributed from each inverter pad was calculated based on the number of inverters and the distance between the inverters and the receivers. The combined noise level at the receivers was the logarithmic sum of the measured noise level and the inverter noise contribution from each group of inverters. Figure 3 shows measured and calculated noise levels at the project site.

Additionally, the analysis calculated the daytime noise levels with inverter noise contribution at the peak traffic noise hour and at quiet (lowest) traffic noise hour. Traffic volume counts near the project site were used to approximate the changes in traffic levels from quiet, average and peak noise hours. Figure 4 shows the daylight changes in noise levels for quiet, average and peak noise hour at the three closest residences to the inverter pads.

Noise levels associated with the new source were compared to applicable standards.

The measured noise data was analyzed to identify site specific noise shielding characteristics based on the topography. The shielding effect of vegetation on noise is qualitatively discussed.

4.0 Noise Levels

4.1 Solar Inverter Noise

Solar inverters convert electricity generated by the solar modules into alternating current. When a 260 kW solar inverter is in operational mode, it emits a buzz which at a distance of 50 feet, sounds as loud as a large business office. Figure 2 gives additional examples of common activities and their associated noise levels. PV Powered (manufacturer of the solar inverters) measured 59 dBA as the noise level for a 260kW inverter at 50 feet.[5] Solar inverter structures measure approximately 8 feet by 8.5 feet by 2 feet.

The change in the noise level at a receiver will depend on the noise contribution from each inverter that can be heard at each receiver. The noise contribution from each inverter depends on the number of inverters that are grouped together at each inverter pad and the distance between each inverter pad and the receiver. Inverters will be installed in groups of 3 to 4 at each location for a total of 10 inverters. There are 3 possible scenarios that inverters may be arranged. The worst case scenario will be presented in this report and Figure 3; the other scenarios are summarized in Appendix A.

4.1.1 Summing Noise Levels of Multiple Inverters

The following noise calculations assume a measured noise level of 59 dBA at 50 feet for one 260 kW inverter. When adding sound levels together the logarithmic rule given in equation 1 is used.

$$A\text{ dBA}+B\text{ dBA}+C\text{ dBA}+D\text{ dBA}=10*\log10\text{^}(10^{(A/10)}+10^{(B/10)}+10^{(C/10)}+10^{(D/10)})$$ equation (1)[6]

Where:
A, B, C and D = different noise sources

This equation shows how 4 different sound levels are added together. Table 2 summarizes the expected noise level at 50 feet from grouped inverters. Three inverters will be located at IM5 and I10. Four inverters will be located at IM7.

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[5] Personal communication to Lynn Averbeck of ODOT from Tucker Ruberti of PVPowered, October 14, 2009.
[6] http://www.fhwa.dot.gov/environment/noise/design/3.htm

Table 2. Addition of Inverter Noise at 50 feet

Number of Inverters	Combined Noise Level (dBA)
1	59
2	$10*\log10\text{^}(10^{(59/10)}+10^{(59/10)}) = 62$
3	$10*\log10\text{^}(10^{(59/10)}+10^{(59/10)}+ 10^{(59/10)}) = 64$
4	$10*\log10\text{^}(10^{(59/10)}+10^{(59/10)}+ 10^{(59/10)} + 10^{(59/10)}) = 65$

4.1.2 Decrease of Noise Level with Increase in Distance

As the distance between the source (inverter pads) and receiver increases, the sound wave dissipates and the noise level at the receiver decreases. Equation 2 calculates the noise level (L_r) at a given distance, if the noise level at a specific distance (50 feet) is known. The equation assumes L_{50} as the noise level at 50 feet which could be either 64 dBA (group of 3 inverters) or 65 dBA (group of 4 inverters).

Table 3 shows the distance (d_r) between each inverter pad and each receiver that was used to calculate the noise contribution (L_r) from the inverter location at each receiver when 4 inverters are placed at IM7 and 3 inverters are placed at I10 and IM5. Tables for noise contributions of other scenarios are presented in Appendix A, Tables A-1 and A-2. All three scenarios predicted identical changes in noise levels. Table 3 also gives the noise contribution from each inverter pad at the receiver.

$$L_r = L_{50} + 20*\log10\,(d_{50}/d_r)\ dBA \qquad \text{equation (2)}$$ [2]

Where:
L_r = sound level at receiver at given distance (dr) dBA
L_{50} = sound level at distance 50 feet dBA
d_{50} = distance of 50 feet
d_r = distance between inverter pad and nearest receiver (feet)

Table 3. Inverter Noise Levels at Various Distances with Four Inverters at IM7				
Location of Source (number of inverters)	**Noise Level at 50 Feet**	**Receiver Location**	**Distance from Source to Receiver**	**Noise Level from Inverters at Receiver**
	dBA		(feet)	Leq/dBA
I10 (3)	64	RM6	800	40
IM5 (3)	64		360	47
IM7 (4)	65		2040	33
I10 (3)	64	RM8	1280	36
IM5 (3)	64		1800	33
IM7 (4)	65		216	52
I10 (3)	64	R11	224	51
IM5 (3)	64		544	43
IM7 (4)	65		1336	36

Note: Locations of inverter pads can be see on Figure 3.

4.2 Measured Noise Levels

Noise levels were measured with a Bruel & Kjaer sound level meters model Type 2221 at various locations at the project site on September 24, 2009. Monitoring locations included the proposed locations for the inverter pads, residences at the western and northern border of the project site, and other selected locations within the project area for collection of project noise data. Other project noise data collected included sound levels measurements for I-205 (M1); the midway elevation of the project site (M2); a location in the solar array (M4); and an additional residential location (RM9). Noise measurements were taken in pairs to ensure the same source of traffic noise and to document any topographical shielding at the site. These measurements were conducted on September 24th, 2009 between 10:00 am and 2:00 pm in an off-peak traffic noise hour to represent the average traffic noise levels. One measurement was also conducted on July 16th between 11:15 am to 11:30 am at M12. Figure 3 shows measured noise levels in dBA.

The noise level taken at M12 was used to represent noise levels at R11 because they both have similar vertical and horizontal distance from I-205 which is the major source of noise. FWHA guidance for noise measurements was followed for these measurements and the noise monitoring sheets are provided in Appendix A. Noise monitoring photographs are included in Appendix B. Table 4 summarizes the measured noise data.

Table 4. Summary of Measured Noise Data for Average Noise Hour			
Measurement Location	Description	Noise Level (Leq/dBA)	Time of Measurement
M1	At I-205 gate to ROW	75	1:08-1:23 pm
M2	East Side, first bench	60	1:08-1:23 pm
M4	Center site, first bench	60	12:24-12:39 pm
IM5	West side, first bench	53	10:33-10:48 am
RM6	Green Street & Salamo Rd, SE corner	64	10:33-10:48 am
IM7	East Side 2, first bench	50	11:41-11:56 am
RM8	East side, second bench	56	11:41-11:56 am
RM9	Center, second bench	52	12:24-12:39 pm
M12*	Empty lot at corner of Salamo Rd & Barrington Drive	58	11:15- 11:30 am
Notes: Noise measurements were taken for 15 minutes and measurements were conducted on September 24, 2009 except M12. *Measurements for M12 were conducted on July 16, 2009			

All noise measurements taken at the project site varied between 50 and 60 dBA except M1 and M6. Noise levels at sites M1 (75 dBA) and M6 (64 dBA) were the loudest and were adjacent to I-205 and Salamo Road, respectively.

4.3 Calculated Existing Noise Levels Before Inverter Installation

4.3.1 Calculated Peak Hour Noise Levels

Peak hour noise levels were calculated by comparing traffic volumes between 10 a.m. and 2 p.m. to peak traffic volumes based on traffic counts of I-205 taken near the project site in June 2009[7]. The data show that traffic volumes between 10 a.m and 2 p.m. are approximately 75% of peak p.m. volumes. Peak noise hour traffic volumes would have to double the hourly traffic volumes observed during noise measurements in order to produce a 3 dBA increase in noise levels. To calculate peak noise hour sound levels conservatively, 3 dBA was added to the measured noise levels.

4.3.2 Calculated Quiet Hour Noise Levels

Daylight, quiet noise hour levels were calculated by comparing traffic volumes between 10 a. m. to 2 p.m. to traffic volumes during the quiet daylight hours. Traffic counts on I-205 near the project site taken in June, 2009 show that traffic volumes between 5 a.m. and 6 a.m., 7 p.m. and 8 p.m. and between 8 p.m. and 9 p.m. were 48%, 67% and 56% of traffic volumes taken between 10 a.m. to 2 p.m., respectively. These hours represent daylight hours in summer when I-205 noise levels would be lowest. Based on the June 2009 traffic volumes, quiet noise hour levels are best approximated by subtracting 3 dBA from noise level measurements which represents a halving of traffic volumes.

7 The traffic data were supplied by Gretchen Harvey, ODOT Traffic System Monitoring Unit.

4.4 Calculated Noise Levels with Inverters

4.4.1 Calculated Noise Levels for Average Noise Hour with Inverter Noise

To estimate the average noise hour, the noise levels at residential receivers when the inverters are operating were calculated by logarithmically summing (Equation 1) the noise level measured at the receivers and the contribution from each of the three grouped inverter pads given in Table 3. The measured noise levels, each inverter pad noise contribution, the total of all inverters noise and the resulting calculated noise level at the receiver for the scenario with 4 solar inverters at IM7 (worst case) are summarized in Table 5. Figure 3 shows the calculated noise levels at 3 residences (RM6, RM8 and R11) with inverter noise. The calculated noise levels are in blue. Noise levels increase by 0 - 2 dBA when inverters are operating. Results for the other two scenarios are presented in Appendix A, Tables A-3 and A-4.

Table 5. Estimated Noise Levels at Average Traffic Noise Hour: Measured Noise Levels and Calculated Inverter Noise Levels at Residential Receivers (Leq/dBA)

Existing Noise Level	New Inverter Noise Contribution from:			Total Inverter Noise Contribution	New Combined Noise Level*	Average Traffic Hour Change in Noise Level
	I10	IM5	IM7			
64 (RM6)	40	47	33	48	64	0
56 (RM8)	36	33	52	52	58	2
58 (R11)	51	43	36	52	59	1

*Added logarithmically with equation 2

Assumes four inverters at location IM7; 3 inverters at I10; and 3 inverters at IM5.

4.4.2 Calculated Noise Levels for Peak Hour Noise Levels

To estimate sound levels for the peak noise hour, noise levels for the peak noise hour were calculated by adding 3 dBA to measured noise levels (See Table 6 column 1). The peak traffic hour noise levels with the inverter noise contribution are shown in Table 6. Using this conservative method, change in noise levels from measured to calculated at peak noise hour increase by 0-1 dBA which are similar or less than the changes in noise levels shown in Table 5 (last column).

Table 6. Estimated Noise Levels at Peak Traffic Noise Hour: Measured Noise Levels and Calculated Inverter Noise Levels at Residential Receivers (Leq/dBA)

Existing Noise Level	New Inverter Noise Contribution from			New Combined Noise Level*	Peak Traffic Hour Change in Noise Level
	I10	IM5	IM7		
64 + 3 = 67 (RM6)	40	47	33	67	0
56 + 3 = 59 (RM8)	36	33	52	60	1
58 + 3 =61 (R11)	51	43	36	62	1

*Added logarithmically with equation 2

Assumes four inverters at location IM7; 3 inverters at I10; and 3 inverters at IM5.

4.4.3 Calculated Noise Levels for Quiet Noise Hour with Inverter Noise

Noise levels for the quiet traffic noise hour during daylight were calculated by subtracting 3 dBA from measured noise levels (See Table 7 column 1) which represents traffic volumes being half the volume of average traffic hour. The quiet hour noise levels with the inverter noise contribution are shown in Table 7. Using this method, change in noise levels from measured to calculated during quiet noise hour increase by 0-3 dBA which is slightly more than increase for average daylight noise hour and which is just perceivable to human ears. These calculations are conservatively assuming that all 10 inverters would operate during those daylight quiet noise hours.

Table 7. Estimated Noise Levels at Quiet Traffic Noise Hour: Measured Noise Levels and Calculated Inverter Noise Levels at Residential Receivers (Leq/dBA)

	New Inverter Noise Contribution from				
Existing Noise Level	**I10**	**IM5**	**IM7**	**New Combined Noise Level***	**Change in Noise Level**
64 - 3 = 61 (RM6)	40	47	33	61	0
56 - 3 = 53 (RM8)	36	33	52	56	3
58 - 3 =55 (R11)	51	43	36	57	2

*Added logarithmically with equation 2

Assumes four inverters at location IM7; 3 inverters at I10; and 3 inverters at IM5.

4.5 Discussion of Calculated Noise Levels for Specific Hours, Specific Seasons

Since solar inverters only operate in daylight hours, the change in noise level varies from season to season based on the number of daylight hours and quiet, average and peak traffic noise hour. Generally, noise levels could increase by up to 3 dBA[8] during the first and last two hours of sunlight during in May, June and July and during the last hour of sunlight in March, April and August. On a worst case summer day, a 3 dBA increase in noise level would occur for a maximum of 13% of time. All other daylight hours will experience a change of 2 dBA or less which is not perceptible to human ears. Table 8 compares the change in noise levels by season and time of day.

[8] Assumes that traffic volumes are half of volumes during peak traffic hour.

Table 8. Seasonal Changes in Noise Level Relative to Hour of Day

Season	Change in Noise Level (dBA)	Traffic Noise Period	Number of Hours That Experience Change	% of Day by Season
Winter (December, January and February)	0	Night time	13	54%
	1	peak noise hour am and pm	5	21%
	2	all other daylight hours	6	25%
Spring (March April)	0	Night time	10	42%
	1	peak noise hour am and pm	5	21%
	2	average daylight noise hour	8	33%
	3	quiet daylight noise hour	1 hour (7pm to 8pm)	**4%**
Summer (May, June and July & August)	0	Night time	8	33%
	1	peak noise hour am and pm	5	21%
	2	average daylight noise hour	8	33%
	3	quiet daylight noise hour	3 (5 to 6am & 7 pm to 9 pm)	**13%**
Fall (September, October and November)	0	Night time	12	50%
	1	peak noise hour am and pm	5	21%
	2	all other daylight hours	7	29%

Notes: For all seasons, peak am daylight traffic noise hour is assumed to be 7 am to 9 am and peak pm daylight traffic noise hour to be 3pm to 6pm; for nighttime hours, the solar inverters are not operating

Spatially, the increase in noise level depends on the distance of receivers from inverter pads. Figure 4 compares the calculated change in noise at the three closest residential receivers for various daylight hours. Houses in the vicinity of RM8 will experience an increase of 3 dBA in noise levels during quiet daylight noise hours. At RM8 for non-quiet hours and for all hours of other locations, residences will experience changes of 2 dBA or less which are not perceptible to human ears.

Comparison of Calculated Noise Levels to New Source Standards

Table 9 shows, the ambient statistical noise level for L_{10} of all inverters operating at the same time compared to the DEQ New Industrial and Commercial Noise Source Standards. The highest noise level by location in the 5th column of Table 5, A3 and A4 were converted from Leq to L_{10} by adding 3 dBA. Noise levels during 7 a. m. to 10 p.m. will be within the noise standard. During daylight hours between 5 a.m. to 7 a.m. when all inverters are operating, L_{10} noise levels could be as high as 56 dBA which is slightly higher than the L_{10} standard of 55 dBA. This approach is conservative; the analysis assumes no muffling of inverter noise. Noise monitoring will be conducted at the project site after the project is completed to determine if noise levels are at acceptable levels. If necessary, noise mitigation will be examined at the project site.

Table 9. Comparison of New Source Contribution Noise Levels to Industrial New Source Standard						
			Day Standard 7 a.m. to 10 p.m.	Below Standard? (dBA Difference)	Night Standard 10 p.m. to 7 a.m.	Below Standard? (dBA Difference)
Location	Leq/dBA	L10/dBA	L10/dBA		L10/dBA	
RM6	49	52	60	yes (-8)	55	yes (-3)
RM8	52	55	60	yes (-5)	55	no (0)
R11	53	56	60	yes (-4)	55	no (+1)
Note: Noise levels from inverters could be 1 dBA higher than standard from 5 a.m. to 7 a.m. from April to August						

5.0 Additional Site Characteristics

5.1 Topography

The project site has 3 distinct geological benches that block the line of sight between receiver at the edge of highway ROW and the dominant noise source (I-205). When topography blocks the line of sight between a source and a receiver, it shields some of the source noise from the receiver. Table 10 arranges the noise measurement data in order of increasing distance from I-205. At IM5 and IM7 the noise levels are lower than expected at the indicated distances from I-205, likely because of the shielding effect of the complex terrain between source and receiver.

Table 10. Change in Noise Levels with Increasing Horizontal Distance from I-205		
ID	Distance from Roadway (feet)	Noise Level (dBA)
M1	88	75
M2	400	60
M4	400	60
IM5	448	**53**
IM7	520	**50**
RM8	736	56
RM9	904	52
Note: Bold values are lower noise levels RM6 was not included in the table as Salamo Road was major noise source.		

5.2 Noise Level Shielding from Trees

A common misconception is that vegetation has sound reducing qualities. The project site contains a number of trees on the first and second benches. The majority of trees that will be removed for the project are located on the second bench. Most of the residences along the northern edge of the project site are 50 to 150 feet higher in elevation than the vegetation being removed; therefore only sparsely spaced treetops are currently visible at these residences. Sparsely spaced treetops do not provide any clearly noticeable noise shielding (5 dBA). Additionally, some of the trees that will be removed are deciduous and provide no noise shielding in winter time.

In order to provide a clearly noticeable decrease in noise levels (5 dBA), vegetation needs to be at least 100 foot wide with a minimum height of 20 feet above the shielded property. The vegetation has to be dense enough that the noise source cannot be seen. There are many trees in the existing project area; however the trees that will be removed are not densely spaced, nor tall enough, and do not completely shield the line of sight for residences 50 to 150 feet higher in elevation than the I-205 roadway, the biggest source of noise for the project site and the surrounding areas. The trees at the project site do not provide a clearly noticeable reduction in traffic noise levels for nearby residences. Therefore the removal of trees in the project area will not create a clearly noticeable increase in the sound levels at bordering residences. The trees on the 3rd bench and at the edges of ODOT ROW will be left in place.

6.0 Conclusions

The West Linn Solar Highway Project will increase noise levels for receivers outside of ODOT right-of-way by up to 2 dBA when the solar inverters operate. This change will not be perceptible to the human ear. However, in spring and summer, during the 1st hour and last two hours of daylight, solar inverters may increase noise levels at residences adjacent to RM8 by up to 3 dBA; this change is just perceptible to human ears. . Since inverters will not operate after dark, nighttime noise levels will not change. The removal of trees at the project site will not create clearly noticeable increases in I-205 noise levels at the closest residents because the trees being removed are not currently thick or tall enough to provide significant noise shielding. There will be minimal tree removal and there will be replanting of trees in other locations at the site. Additional noise shielding at residences will be provided by the site topography in instances where the line of sight between the roadway and the residences is blocked.

Noise monitoring will be conducted after the project is built to confirm that noise levels are at acceptable levels as calculated in this report. If necessary, noise mitigation will be examined and addressed at the project site.

7.0 References

National Environmental Policy Act (http://ceq.hss.doe.gov/Nepa/regs/nepa/nepaeqia.htm)

Appendix A

Noise Level Calculations for Other Scenarios

Table A1a. Inverter Noise Levels at Various Distances with Four Inverters at I10

Location of Source (number of inverters)	Noise Level at 50 Feet	Receiver Location	Distance from Source to Receiver	Noise Level from Inverters at Receiver
	dBA		(feet)	dBA
I10 (4)	65	RM6	800	41
IM5 (3)	64		360	47
IM7 (3)	64		2040	32
I10 (4)	65	RM8	1280	37
IM5 (3)	64		1800	33
IM7 (3)	64		216	51
I10 (4)	65	R11	224	52
IM5 (3)	64		544	43
IM7 (3)	64		1336	36

Table A1b. New Noise Levels with Inverters at Sensitive Receivers (Leq/dBA)

Existing Noise Level	New Inverter Contribution from			Total Inverter Contribution*	New Combined Noise Level	Change in Noise Level
	I10	IM5	IM7			
64 (RM6)	41	47	32	48	64	0
56 (RM8)	37	33	51	51	57	1
58 (R11)	52	43	36	53	59	1

*Added logarithmically with equation 2
Assumes four inverters at location I10; 3 inverters at IM5, 3 inverters at IM7

Table A2a. Inverter Noise Levels at Various Distances with Four Inverters at IM5

Location of Source (number of inverters)	Noise Level at 50 Feet	Receiver Location	Distance from Source to Receiver	Noise Level from Inverters at Receiver
	dBA		(feet)	Leq/dBA
I10 (3)	64	RM6	800	40
IM5 (4)	65		360	48
IM7 (3)	64		2040	32
I10 (3)	64	RM8	1280	36
IM5 (4)	65		1800	34
IM7 (3)	64		216	51
I10 (3)	64	R11	224	51
IM5 (4)	65		544	44
IM7 (3)	64		1336	35

Table A2b. New Noise Level with Inverters at Sensitive Receiver (Leq/dBA)						
	New Inverter Contribution from				New Combined Noise Level	Change in Noise Level
Existing Noise Level	I10	IM5	IM7	Total Inverter Contribution*		
64 (RM6)	40	48	32	49	64	0
56 (RM8)	36	34	51	51	57	1
58 (R11)	51	44	35	52	59	1

*Added logarithmically with equation 2
Four inverters at location IM5, 3 inverters at I10, 3 inverters at IM7

Appendix B

Noise Monitoring Sheets

OREGON DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION – GEO-ENVIRONMENTAL SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M1
PROJECT NAME: Solar Project
DATE Sept 24, 2009.
HIGHWAY NAME AND NUMBER: 205
ENGINEER NL
COUNTY: ____
WIND: < 5mph
START TIME: 1:08 **STOP TIME:** 1:23 **CALIBRATION TONE** 94 **dB** ____ **HZ**
before 93.7 dB
LENGTH OF MEASUREMENT: 15
LEQ RANGE: 45-105
MICROPHONE HEIGHT: 5feet
SEL: ____

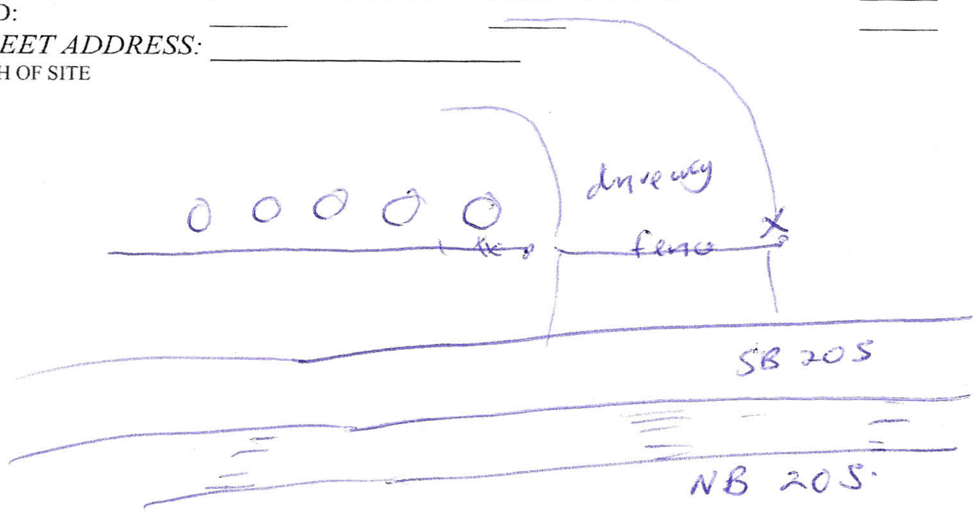
LEQ: ____

OPTIONAL

LEQ @ 5 MIN	74.7	LEQ@ 25 MIN		LEQ@ 45 MIN			
LEQ @ 10 MIN	74.8	LEQ@ 30 MIN		LEQ@ 50 MIN		SEL - LEQ: =	
LEQ @ 15 MIN	75.0	LEQ@ 35 MIN		LEQ@ 55 MIN			
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN		TIME FROM TABLE:	

TRAFFIC:	ROADWAY: ____ COUNTED	HR. EQUIV.	ROADWAY: ____ COUNTED	HR. EQUIV.	ROADWAY: ____ COUNTED	HR. EQUIV.
AUTOS:	=		=		=	
MED. TRUCKS:	=		=		=	
HEAVY TRUCKS:	=		=		=	
SPEED:						

STREET ADDRESS: ____
SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)
SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION – GEO./HYDRO SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M2

PROJECT NAME: Solar Hwy West Linn
DATE 9
HIGHWAY NAME AND NUMBER: ______
ENGINEER ______
COUNTY: ______
WIND: ______

START TIME: 1:08:30 p **STOP TIME:** 1:23:30 **CALIBRATION TONE** 93.8 **dB** ____ **HZ**

LENGTH OF MEASUREMENT: 15' (15, 23) **LEQ RANGE:** 45-105
MICROPHONE HEIGHT: ______
SEL: ______

LEQ: 60.0

OPTIONAL

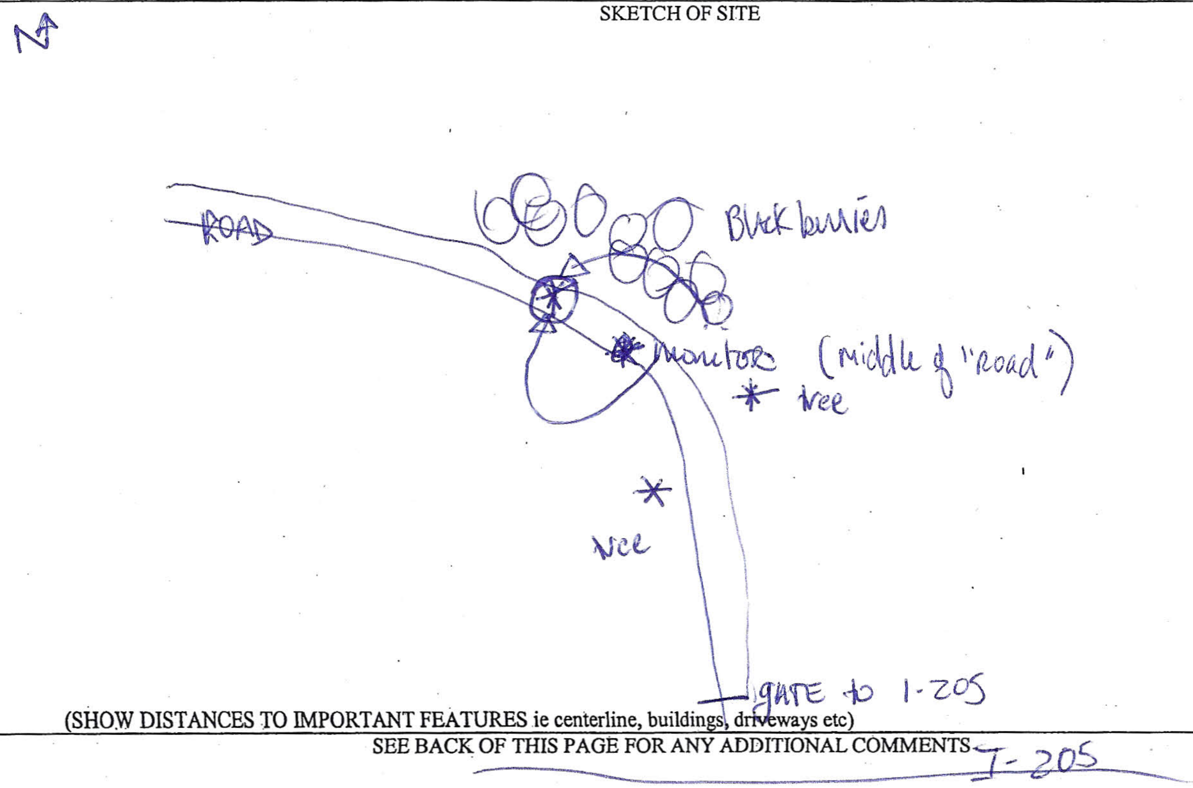
13	LEQ @ 5 MIN 59.4	LEQ@ 25 MIN ____	LEQ@ 45 MIN ____	
18	LEQ @ 10 MIN 59.7	LEQ@ 30 MIN ____	LEQ@ 50 MIN ____	SEL - LEQ: = ____
23	LEQ @ 15 MIN 60.0	LEQ@ 35 MIN ____	LEQ@ 55 MIN ____	
	LEQ @ 20 MIN ____	LEQ@ 40 MIN ____	LEQ@ 60 MIN ____	TIME FROM TABLE: ____

TRAFFIC:

	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:		=		=		=
MED. TRUCKS:		=		=		=
HEAVY TRUCKS:		=		=		=
SPEED:						

STREET ADDRESS: ______

SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)

SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

OREGON DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION – GEO-ENVIRONMENTAL SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M4
PROJECT NAME: Solar Project
DATE 9-24-09.
HIGHWAY NAME AND NUMBER: 205
ENGINEER NL
COUNTY: ______
WIND: <5 mph
START TIME: 12:24 **STOP TIME:** 12:39 **CALIBRATION TONE** 94 dB ______ HZ
Before 93.7 after 93.7
LENGTH OF MEASUREMENT: 15 min
LEQ RANGE: ______
MICROPHONE HEIGHT: 5 feet
SEL: ______

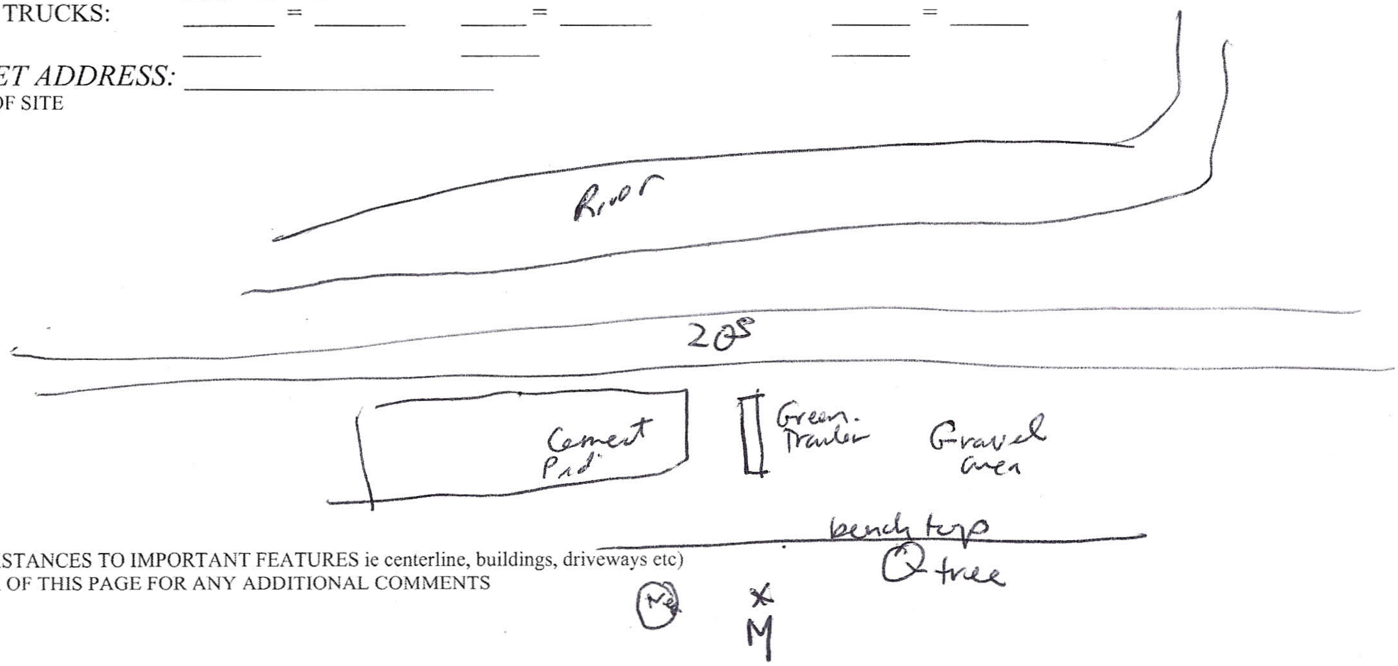
LEQ: 59.5

OPTIONAL

LEQ @ 5 MIN	59.7	LEQ@ 25 MIN		LEQ@ 45 MIN			
LEQ @ 10 MIN	59.4	LEQ@ 30 MIN		LEQ@ 50 MIN		SEL - LEQ: =	
LEQ @ 15 MIN	59.5	LEQ@ 35 MIN		LEQ@ 55 MIN			
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN		TIME FROM TABLE:	

TRAFFIC:	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:	=		=		=	
MED. TRUCKS:	=		=		=	
HEAVY TRUCKS:	=		=		=	
SPEED:						

STREET ADDRESS: ______
SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)
SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION – GEO./HYDRO SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M5
PROJECT NAME: Solar Hwy West Linn
DATE 9/24/09
HIGHWAY NAME AND NUMBER: I 205
ENGINEER Newvine
COUNTY: Mult
WIND: calm < 5 mph

START TIME: 10:33:50 A **STOP TIME:** 10:48:50
CALIBRATION TONE 94.0 **dB** ______ **HZ** @ 10:30 AM

LENGTH OF MEASUREMENT: 15'
LEQ RANGE: 45 - 105
MICROPHONE HEIGHT: 6' ft
SEL: ______

LEQ: 53.1

OPTIONAL

LEQ @ 5 MIN	52.1	LEQ@ 25 MIN		LEQ@ 45 MIN	
43 LEQ @ 10 MIN	52.7	LEQ@ 30 MIN		LEQ@ 50 MIN	
48 LEQ @ 15 MIN	53.1	LEQ@ 35 MIN		LEQ@ 55 MIN	
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN	

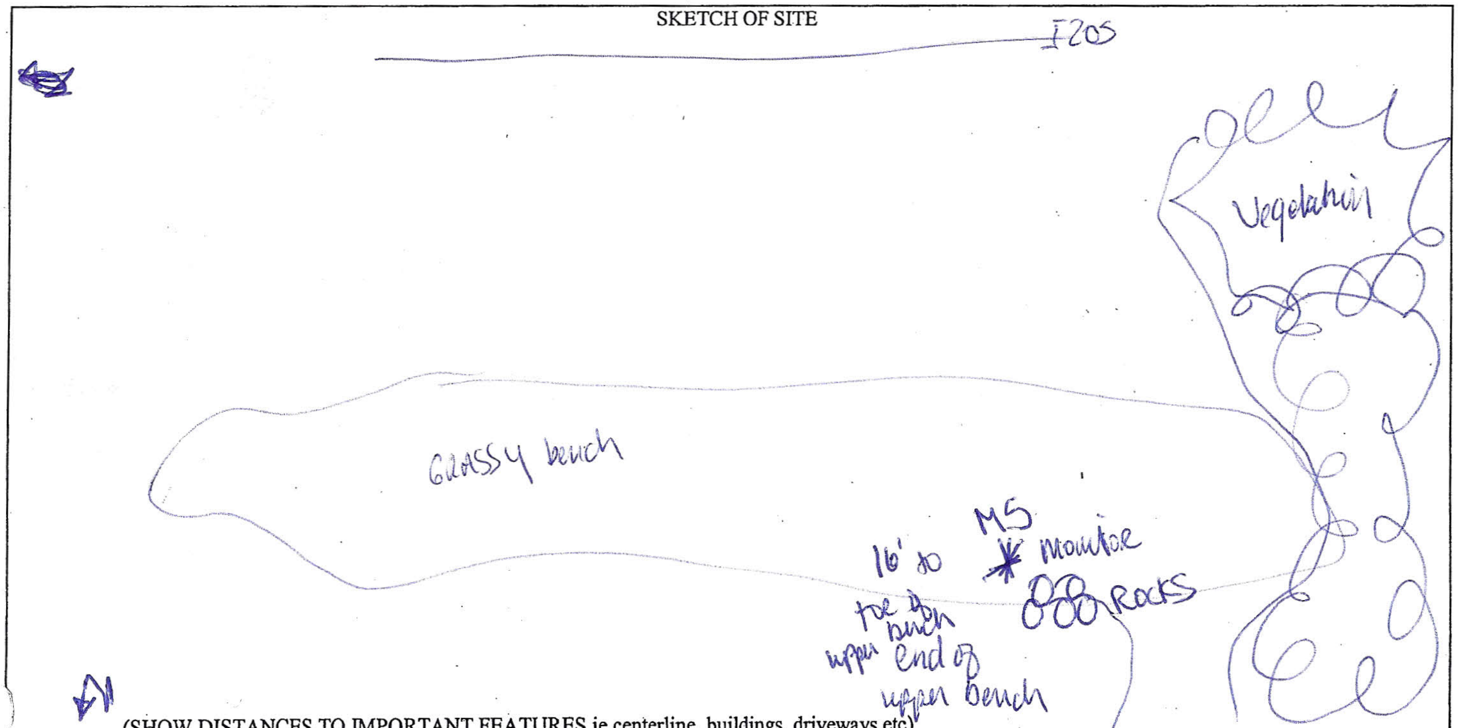
SEL - LEQ: = ______

TIME FROM TABLE: ______

TRAFFIC:	ROADWAY: COUNTED		HR. EQUIV.	ROADWAY: COUNTED		HR. EQUIV.	ROADWAY: COUNTED		HR. EQUIV.
AUTOS:		=			=			=	
MED. TRUCKS:		=			=			=	
HEAVY TRUCKS:		=			=			=	
SPEED:	55-65 on I205								

STREET ADDRESS: ODOT ROW

SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)

SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

OREGON DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION – GEO-ENVIRONMENTAL SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M6
PROJECT NAME: Solar Project
DATE 9-24-2009
HIGHWAY NAME AND NUMBER: 205
ENGINEER NL
COUNTY: ____
WIND: < 5 mph.
START TIME: 10:33 am **STOP TIME:** 10·18 **CALIBRATION TONE** 94 **dB** 0 **HZ**

LENGTH OF MEASUREMENT: 15 min
LEQ RANGE: 45-105 dB before 93.7dB
MICROPHONE HEIGHT: 5 feet
SEL: ____

LEQ: ____

OPTIONAL

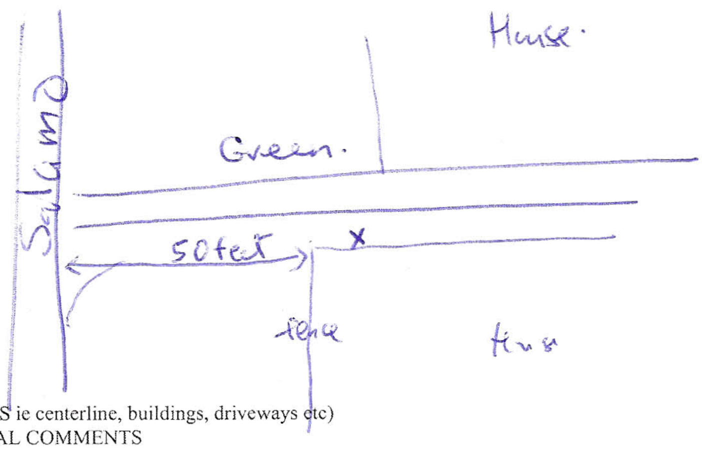
LEQ @ 5 MIN		LEQ@ 25 MIN		LEQ@ 45 MIN			
LEQ @ 10 MIN	63.4	LEQ@ 30 MIN		LEQ@ 50 MIN		SEL - LEQ: =	
LEQ @ 15 MIN	64.3	LEQ@ 35 MIN		LEQ@ 55 MIN			
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN		TIME FROM TABLE:	

TRAFFIC:	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:	=		=		=	
MED. TRUCKS:	=		=		=	
HEAVY TRUCKS:	=		=		=	
SPEED:						

STREET ADDRESS: ____
SKETCH OF SITE

intermittent traffic
20-30 cars/min
2-4 medium truck

some garden equipment
blower at 10am



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)
SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

9:50 am.
9:57 64.8dBA
10:00 65.0

with blower.
2 houses away

OREGON DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION – GEO-ENVIRONMENTAL SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M7
PROJECT NAME: Solar Project
DATE 9-24-09
HIGHWAY NAME AND NUMBER: 205
ENGINEER NL
COUNTY: ____
WIND: < 5 mph
START TIME: 11:41 **STOP TIME:** 11:56 **CALIBRATION TONE** 94 **dB** ____ **HZ**
93.7 before 93.7 after
LENGTH OF MEASUREMENT: 15 minutes
LEQ RANGE: 45-105
MICROPHONE HEIGHT: 5 feet
SEL: ____

LEQ: ____

OPTIONAL

LEQ @ 5 MIN	51.1	LEQ@ 25 MIN		LEQ@ 45 MIN	
LEQ @ 10 MIN	50.3	LEQ@ 30 MIN		LEQ@ 50 MIN	
LEQ @ 15 MIN	50.2	LEQ@ 35 MIN		LEQ@ 55 MIN	
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN	

SEL - LEQ: = ____

TIME FROM TABLE: ____

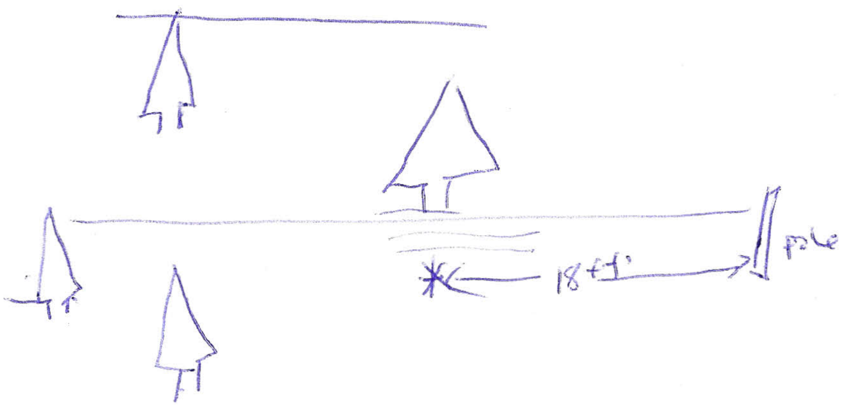
TRAFFIC: No traffic counts, not visible.

	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:	=		=		=	
MED. TRUCKS:	=		=		=	
HEAVY TRUCKS:	=		=		=	
SPEED:						

STREET ADDRESS: ____

SKETCH OF SITE

overcast, dry



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)
SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

During setup waiting 51.6 dBA 10 minutes steady hum from freeway

OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION – GEO./HYDRO SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: ~~M4~~ M8 (cmm)
PROJECT NAME: Solar Hwy
DATE 9/24
HIGHWAY NAME AND NUMBER: –
ENGINEER Newvine
COUNTY: Mult
WIND: calm < 5 mph

START TIME: 11:42:08 (13) **STOP TIME:** 11:57:08
CALIBRATION TONE 93.9 **dB** ______ **HZ**

LENGTH OF MEASUREMENT: 15
LEQ RANGE: 55.9 dBA
MICROPHONE HEIGHT: ________
SEL: ________

LEQ: ________

OPTIONAL

47 LEQ @ 5 MIN	~~47~~ 57.0	LEQ@ 25 MIN		LEQ@ 45 MIN	
52 LEQ @ 10 MIN	56.1	LEQ@ 30 MIN		LEQ@ 50 MIN	
LEQ @ 15 MIN		LEQ@ 35 MIN		LEQ@ 55 MIN	
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN	

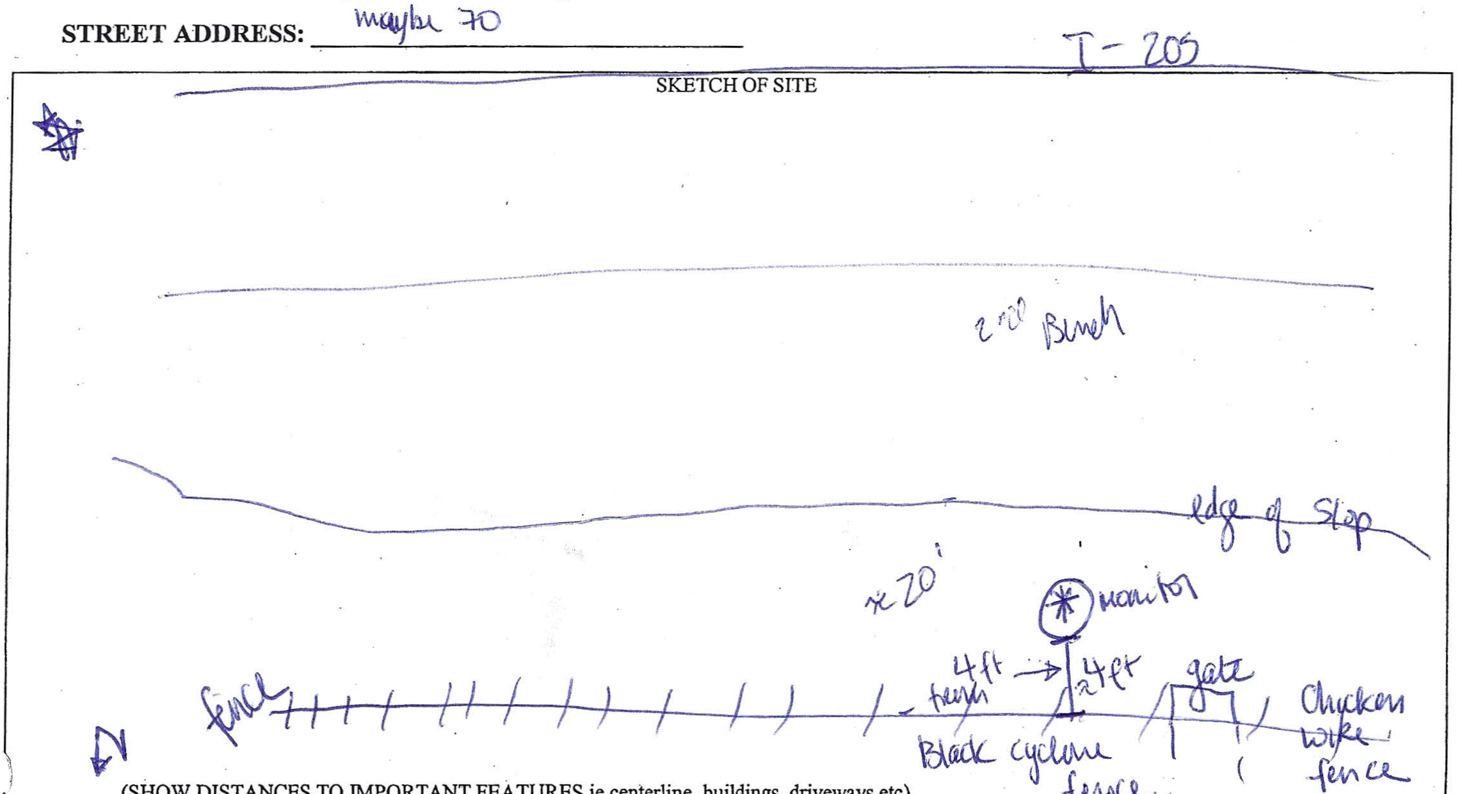
SEL - LEQ: = ________

TIME FROM TABLE: ________

TRAFFIC:	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:						
MED. TRUCKS:						
HEAVY TRUCKS:						
SPEED:	55-65 on I205 maybe 70					

STREET ADDRESS: ________

SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)
SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

edge of property
path to home

OREGON DEPARTMENT OF TRANSPORTATION

HIGHWAY DIVISION – GEO./HYDRO SECTION
NOISE MEASUREMENT RECORD
(USING AN INTEGRATING SOUND LEVEL METER)

MEASUREMENT NO: M9
DATE 9/24/09
ENGINEER ____
WIND: ____

PROJECT NAME: Solar Hwy
HIGHWAY NAME AND NUMBER: ____
COUNTY: ____

START TIME: 12:24:08 **STOP TIME:** 12:39:08

CALIBRATION TONE ____ **dB** ____ **HZ**

LENGTH OF MEASUREMENT: 15'

LEQ RANGE: ____
MICROPHONE HEIGHT: ____
SEL: ____

LEQ: 52.1

OPTIONAL

29 LEQ @ 5 MIN	52.4	LEQ@ 25 MIN		LEQ@ 45 MIN	
34 LEQ @ 10 MIN	51.8	LEQ@ 30 MIN		LEQ@ 50 MIN	
LEQ @ 15 MIN	52.1	LEQ@ 35 MIN		LEQ@ 55 MIN	
LEQ @ 20 MIN		LEQ@ 40 MIN		LEQ@ 60 MIN	

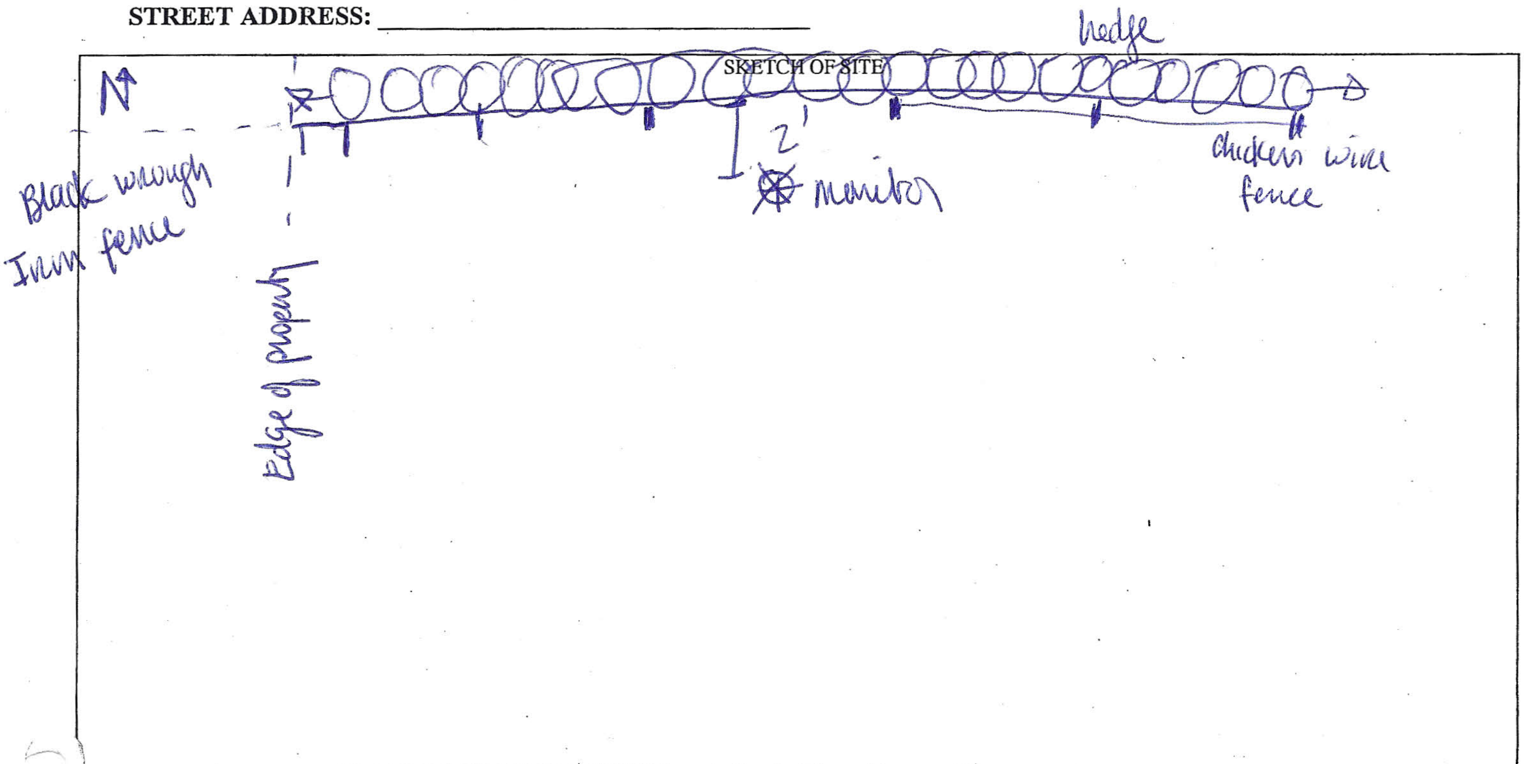
SEL - LEQ: = ____

TIME FROM TABLE: ____

TRAFFIC:	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.	ROADWAY: COUNTED	HR. EQUIV.
AUTOS:						
MED. TRUCKS:						
HEAVY TRUCKS:						
SPEED:						

STREET ADDRESS: ____

SKETCH OF SITE



(SHOW DISTANCES TO IMPORTANT FEATURES ie centerline, buildings, driveways etc)

SEE BACK OF THIS PAGE FOR ANY ADDITIONAL COMMENTS

C:\usr\Word\MEASUREMENT DATA SHEET.doc 03/29/07

Appendix B

Noise Monitoring Photographs

Looking south towards I-205 southbound lanes

Looking southeast towards I-205 southbound lanes

Looking northeast towards property

Looking north towards property

Looking northwest towards paved area within property

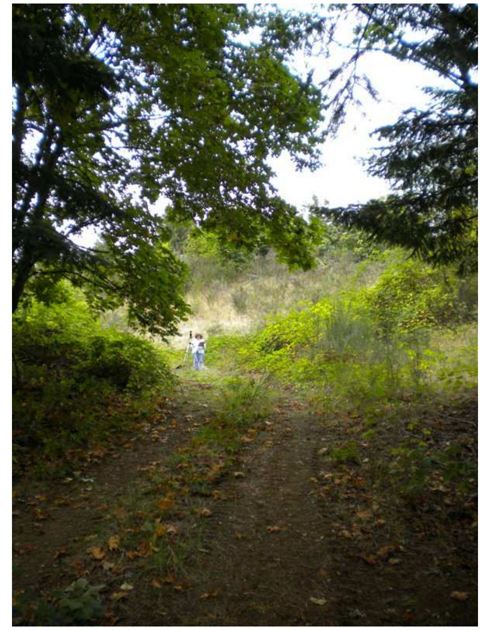
Looking west along property edge

Noise reading of 75 dBA

Noise Monitoring towards M1

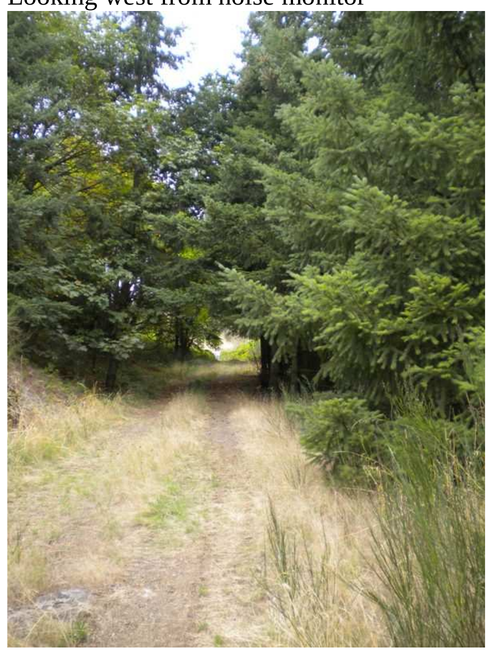
Looking south from noise monitor

Looking west from noise monitor



Looking north towards monitor

Looking north of monitor



Looking south from monitor

Noise reading of 60 dBA

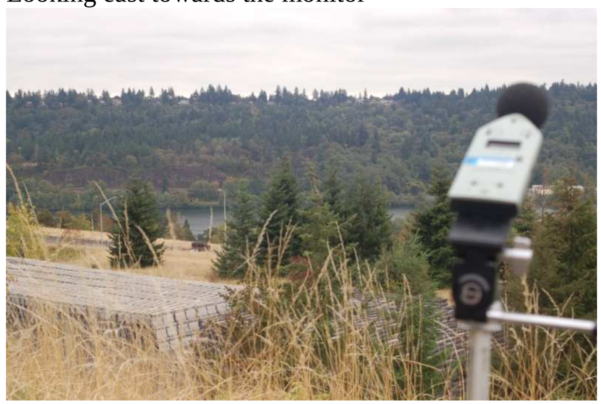
Noise Monitor M2


Looking south towards monitor


Looking east towards the monitor


Noise reading of 59.5 dBA


Looking west towards monitor


Looking southeast towards monitor


Looking north towards monitor


Looking southwest towards monitor

Noise Monitor M4


Looking east towards monitor

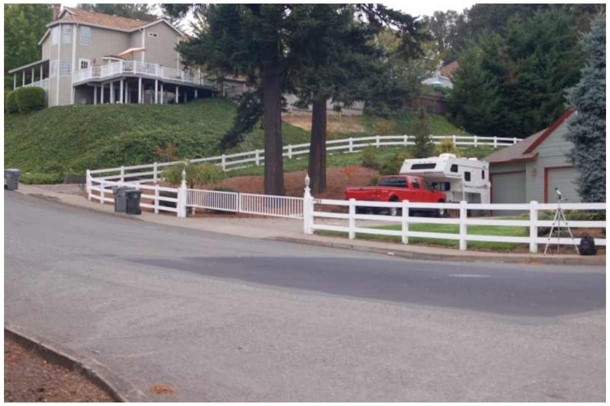

Looking west towards monitor


Noise reading of 53.7 dBA


Looking north towards monitor

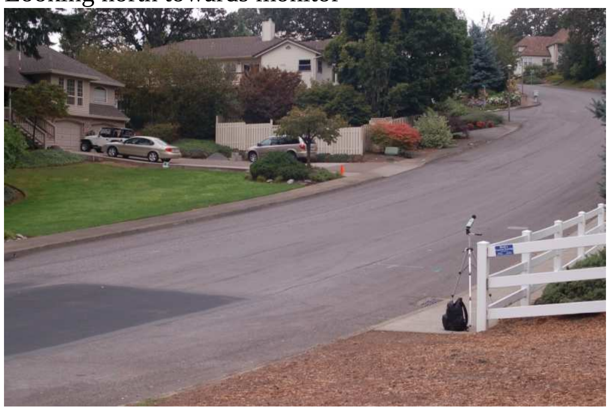

Looking south towards monitor

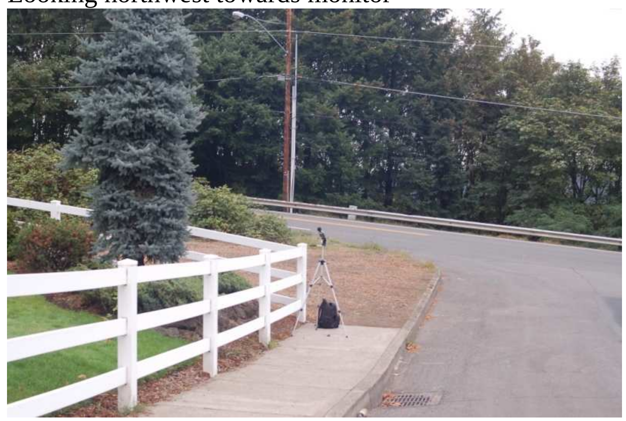
Noise Monitor IM5


Looking north towards monitor


Looking northwest towards monitor


Looking north towards monitor


Looking west towards monitor


Looking southeast toward monitor

Noise reading of 64.3 dBA

Noise Monitor RM6


Looking north from monitor


Looking east towards monitor


Looking northeast from monitor


Looking south from monitor


Looking south from monitor

Noise reading of 50.2 dBA

Noise Monitor IM7


Looking west from monitor


Looking southwest from monitor


Looking east from monitor


Looking north from monitor

Noise reading of 55.9 dBA

Noise Monitor RM8

Looking west towards noise monitor

Looking southeast towards monitor

Noise reading of 52.1 dBA

Looking southwest towards monitor

Looking east towards monitor

Noise Monitor RM9


Looking northwest from monitor


Looking east from monitor

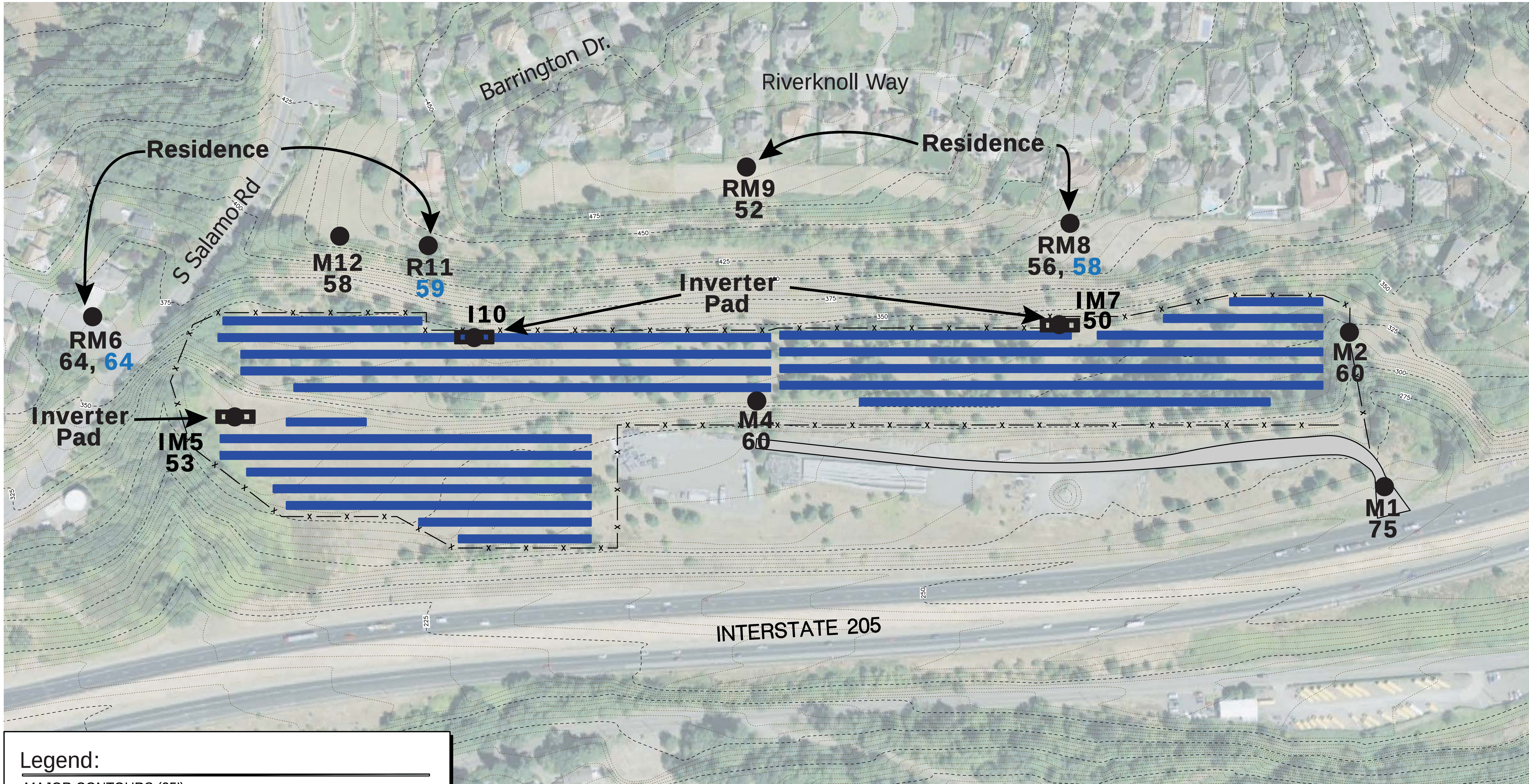

Looking south from monitor


Looking north from monitor


Looking southeast towards monitor


Looking northeast from monitor

Noise Monitor R11



Legend:

MAJOR CONTOURS (25')	- - - - - -
MINOR CONTOURS (5')	··········
PROPOSED FENCE	—x—x—x—
PHOTOVOLTAIC ARRAY	
EXISTING ENTRANCE	
INVERTER LOCATIONS	
NOISE LOCATION	
NOISE LEVEL (dBA)	(Measured, Calculated With Inverter)

DATE: 04/03/2009

0 50 100 200

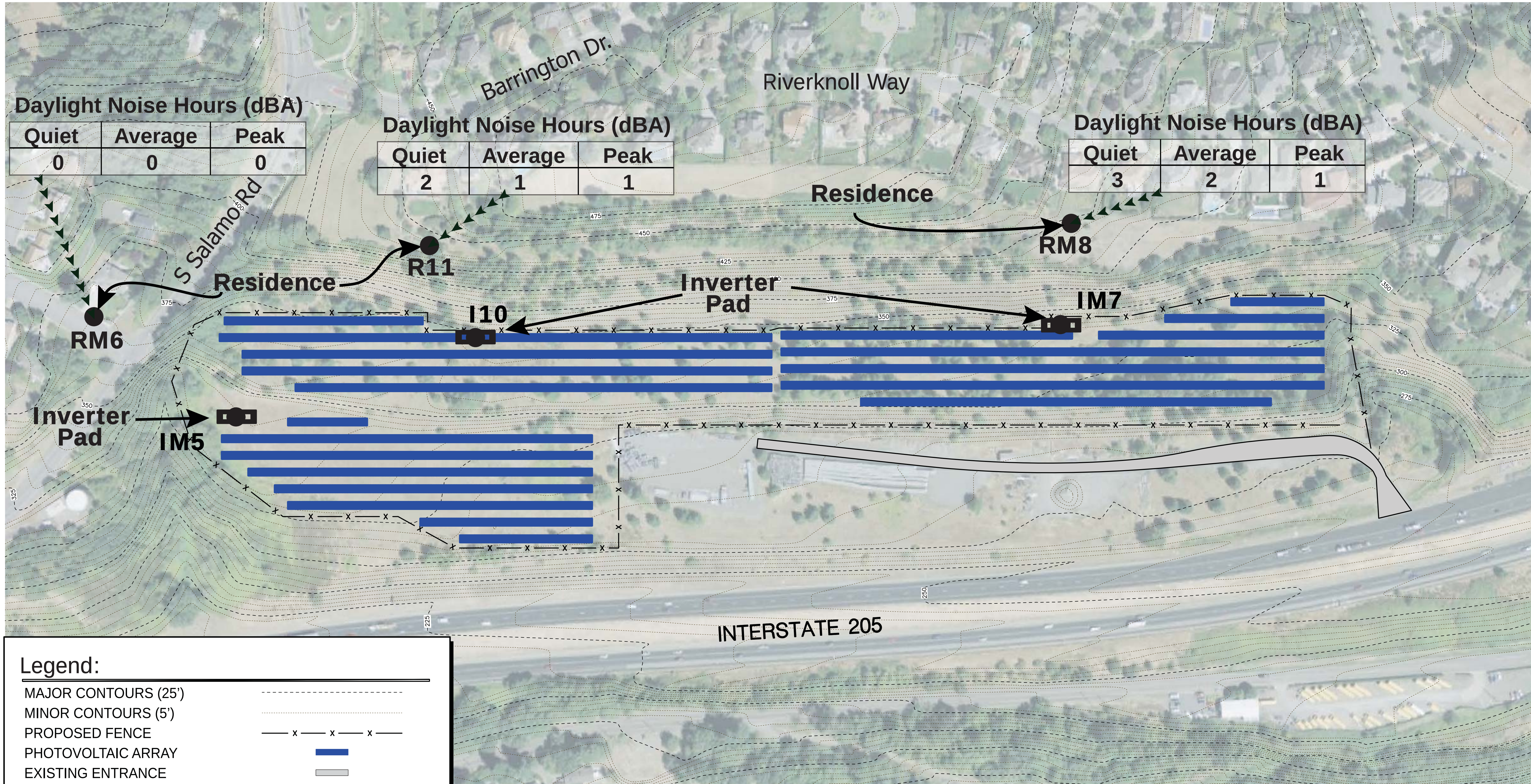
Figure 3. Noise Measurements and Calculated Noise Level with Inverter Noise Contribution

ODOT Solar Power Facility (West Linn)

I-205, Clackamas County

Moyano LEADERSHIP GROUP INC.

Cardno WRG



Legend:

MAJOR CONTOURS (25')	
MINOR CONTOURS (5')	
PROPOSED FENCE	
PHOTOVOLTAIC ARRAY	
EXISTING ENTRANCE	
INVERTER LOCATIONS	
NOISE LOCATION	

Notes:

Quiet Daylight Noise Hour	5am - 6am, 8pm - 9pm in Spring or Summer
Average Noise Hour	All other daylight hours
Peak Noise Hours	7am -9am and 3pm - 6pm all Seasons

DATE: 04/03/2009

0 50 100 200

Figure 4. Change In Noise Levels at Residences By Hour of Day

ODOT Solar Power Facility (West Linn)

I-205, Clackamas County

Moyano LEADERSHIP GROUP INC. Cardno WRG