GUARDRAIL INSTALLATION NOISE LEVEL EVALUATION FINAL REPORT

STATE PLANNING AND RESEARCH PROGRAM PROJECT 315

by

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Washington, D.C. 20590

June 1999

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA-OR-RD-99-23		

4. Title and Subtitle	5. Report Date
Guardrail Installation Noise Level Evaluation Final Report	June 1999
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Rick Poecker and Brett Sposito	

9. Performing Organization Name and Address			10. Work Unit No. (TRAIS)
Oregon Department of Transportation Research Group 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192	and	Oregon Department of Transportation Environmental Services Unit 1158 Chemeketa Street NE Salem, Oregon 97301	
			11. Contract or Grant No. SPR 315

12. Sponsoring Agency Name and Address			13. Type of Report and Period Covered
Oregon Department of Transportation Research Group 200 Hawthorne SE, Suite B-240 Salem, Oregon 97301-5192	and	Federal Highway Administration Washington, D.C. 20590	Final Report July 1998 to June 1999
			14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

The Oregon Department of Transportation (ODOT) Environmental Services Unit evaluates the impacts of noise and mitigation of noise issues. ODOT currently requires noise level evaluation for proposed construction projects when threatened or endangered wildlife may be adversely affected.

A commonly used piece of equipment on construction projects is the guardrail post driver. The guardrail post driver does not have a baseline noise level established. As a substitute, ODOT biologists have used the baseline noise level associated with the pile driver for noise level assessments. This study establishes a more accurate baseline noise level for the guardrail post driver, which is lower than the baseline noise level of the pile driver. Due to this lower noise level, there is a potential increase in safety and decrease in cost.

17. Key Words	18. Distribution Statement
Construction Noise, Guardrail Installation, Noise, Noise Disturbance, Post Driver	Copies available from NTIS

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Unclassified	Unclassified	16	

Technical Report Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

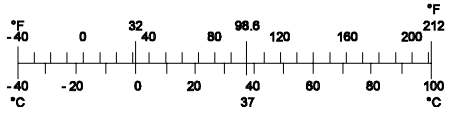
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	Inches	25.4	Millimeters	Mm
ft	Feet	0.305	Meters	M
yd	Yards	0.914	Meters	M
mi	Miles	1.61	Kilometers	Km
		AREA		
in^2	square inches	645.2	Millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	Acres	0.405	Hectares	Ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	ML
gal	Gallons	3.785	Liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	Ounces	28.35	Grams	G
lb	Pounds	0.454	Kilograms	Kg
T	short tons (2000 lb)	0.907	Megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	miles	mi
		AREA		
Mm^2	millimeters squared	0.0016	square inches	in^2
M^2	meters squared	10.764	square feet	ft^2
Ha	hectares	2.47	acres	ac
Km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
ML	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
M^3	meters cubed	35.315	cubic feet	ft^3
M^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
G	grams	0.035	ounces	oz
Kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



***** SI is the symbol for the International System of Measurement (4-7-94 jbp)

ACKNOWLEDGEMENTS

Thank you to the Technical Advisory Committee for their efforts, assistance and guidance:
- Dave Goodwin, ODOT Environmental Services Unit
- Elton Chang, FHWA
- Larry Lindley, ODOT Region 2 Project Management Office
- Rose Owens, ODOT Environmental Services Unit
- John Riedl, ODOT Environmental Services Unit, Engineering Unit Manager
- Eb Engelmann, ODOT Project Support Section Manager

A special thank you to the following employees of Lane County Public Works Department:
- Doug Putschler
- Arno Nelson
- George Harrison

Thank you to the following individuals for assistance with locating guardrail installation projects:
- Larry Arnold, Coral Construction Company
- Moe McNabb, Dirt and Aggregate Interchange Inc.

Thank you also to those who assisted with the review and edit of this report:
- Liz Hunt, ODOT Research Group
- Joni Reid, ODOT Research Group

DISCLAIMER

GUARDRAIL INSTALLATION NOISE LEVEL EVALUATION
FINAL REPORT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PHOTOS/FIGURES

1.0 INTRODUCTION

Spotted owls, marbled murrelets, bald eagles, peregrine falcons and other wildlife species are sensitive to noise disturbances. When threatened or endangered species such as these are nearby, construction must be restricted to times when the species are least likely to be disturbed or mitigation measures must be implemented to reduce noise disturbances. Noise-producing activities that are predicted to be 10 decibels measured in the A-scale filtering level (dBA) or more above background levels at a nest site or sensitive feeding area are generally prohibited during certain periods of the year, unless an Endangered Species Act incidental take permit is obtained. As a point of reference, the normal range of human hearing can detect a 3 dBA change in sound pressure. This study establishes baseline guardrail installation noise levels with which to calculate what noise levels would attenuate to at a sensitive site. Often times, installation of guardrail systems is in rural, wooded settings that are habitat areas of threatened and endangered species, as in Figure 1.1.

Figure 1.1: Installed posts and guardrail

1.1 NOISE LEVEL EVALUATION OF PROJECTS

The Oregon Department of Transportation (ODOT) Environmental Services Unit evaluates the impacts and mitigation of noise issues. ODOT currently requires noise level evaluation of proposed construction projects when threatened or endangered wildlife may be adversely affected. Noise levels from other construction activities, such as grading, grinding and paving, have been previously studied. These noise levels have typically not changed over the years and do not warrant further study. No noise studies had been accomplished on guardrail installation equipment. In the past, with no better information to go by, ODOT biologists have generalized that noise levels of a guardrail post driver are similar to or slightly quieter than a pile driver.

For example, there is a seasonal restriction for construction on the Willamette Highway from milepost 64 to 70. Eagles are a protected species in this region. Without adequate noise information to calculate with, ODOT biologists must assume the worst case in evaluating potential noise impacts, and this usually results in a very restrictive construction timeline for guardrail installation in the proximity of sensitive nesting and feeding sites.

1.2 FIELD NOISE MEASUREMENTS OF GUARDRAIL INSTALLATION

The study addresses the perceived difference in noise levels from installing wood or steel posts. Because steel posts have a smaller cross-sectional area, it was assumed that the installation noise levels might be lower for steel than for wood.

Noise level measurements of both wood and steel guardrail post installations were conducted at a control site. Then, noise level measurements of both wood and steel guardrail posts were conducted at two separate construction sites each. Figure 1.2 is an example of one of the wood installation sites and Figure 1.3 is an example of one of the steel installation sites.

Figure 1.2: Wood post installation, Elkton-Sutherlin Highway (Elkton)

Figure 1.3: Steel post installation, Old Brownsville Road (Brownsville)

2.0 BACKGROUND

2.1 CONSTRUCTION NOISE LEVELS

The typical noise levels of various construction equipment, found in *Fundamentals and Abatement of Highway Traffic Noise,* US Department of Transportation, 1973, and *Fundamentals of Noise and Vehicle Exterior Noise Levels,* Western Highway Institute, 1971, are routinely used in noise attenuation calculations. There is no need to reevaluate the noise levels listed in these publications. It is necessary, however, to establish a similar baseline for any equipment not included in the publications. The guardrail post driver is not included in the publications nor could other noise level test results be found.

2.2 TYPES OF NOISE LEVEL MEASUREMENTS

The effects of pile driver noise on threatened and endangered species was documented in a report done by the Washington Department of Transportation (*Noise Disturbance Study on Bald Eagles at Orcas and Shaw Island Ferry Terminals,* 1987). Noise levels in that report were quantified using Leq/dBA, or hourly sound level equivalent using the A scale filtering level, and Lmax/dBA, or maximum sound level using the A scale filtering level. Therefore, noise levels for this guardrail post driving report will also be quantified using Leq/dBA and Lmax/dBA. Noise levels will also be documented using L5 (5% of the sound level measurements exceed this level over time) and L10 (10 % of the sound level measurements exceed this level over time), as some local noise ordinances refer to these. The 1987 Washington study documents that there are no known standards to determine what is an acceptable noise level for working around threatened and endangered species. However, in the report an assumed acceptable noise level was less than Leq 65 dBA or an increase in noise of less than 10 dBA above the background noise Leq/dBA levels.

2.3 COMPARISON OF PILE DRIVER AND GUARDRAIL POST DRIVER NOISE LEVELS

Biologists have had little baseline information to estimate noise levels from guardrail installation projects, and have often used the typical noise levels associated with pile driving operations. However, guardrail installation noise levels were perceived to be lower than pile driving noise levels. Noise levels associated with guardrail post driving operations, as verified by measurements at a control site and at actual construction sites, are summarized in Section 3.0.

Another difference between pile driving and guardrail post driving noise sources may be the noise attenuation rates. Guardrail post driving occurs from about 1 to 4 m above the ground level. Pile driving typically occurs 6 to 12 m above the ground level. Because of the height difference, the noise from guardrail post driving is expected to be influenced by ground effects (soft site, hard site), where the noise emitted from pile driving operations would typically not be influenced by ground effects, and would be expected to have a lower drop-off rate. Added shielding by topography and other shielding could offset the difference in attenuation rates, depending on site conditions found between the noise source and the receiver.

2.4 SEARCH FOR NOISE REDUCING MEASURES FOR GUARDRAIL POST DRIVERS

An informal survey of noise experts and contractors by the authors found no viable cushioning techniques to reduce guardrail installation noise. As a note, the weight drop post driver used by Lane County at the Wheeler Road (Pleasant Hill) control site and at the Wallace Creek Road (Jasper) construction site had a composite block placed on top of the steel post cover.

3.0 NOISE MEASUREMENT OF GUARDRAIL POST DRIVING

3.1 SITE SELECTION

The ODOT Environmental Services Unit and the ODOT Research Group selected sites to measure the noise levels of guardrail post installation. Sites were selected by calling the companies that install guardrail post and matching their schedules with the schedules of the authors. The sites are listed in the Appendix.

3.2 TYPES OF NOISE MEASUREMENTS

The following measurements were taken to evaluate the noise levels at the guardrail post driving sites:

- Leq/dBA – Hourly sound level equivalent using the A scale filtering level
- Lmax/dBA – Maximum sound level using the A scale filtering level
- L5 – 5% of the sound level measurements exceed this level over time
- L10 – 10 % of the sound level measurements exceed this level over time
- Continuous Leq/dBA – Continuous measurement of overall noise levels of entire operation at a fixed point, to include the post driving machine start up, revving, post driving, and moving onto the next post to be driven, continuing through all the posts (by type) to be driven

Continuous Leq/dBA noise measurements were taken with a B&K 2221 Sound Level Meter for all sites. All other noise measurements were taken with a Quest 1900 Sound Level Meter. All noise measurements were taken with slow "A" weighting. The sound level meters used for this study are pictured in Figure 3.1.

Figure 3.1: Sound level meter set-up, Wallace Creek Road (Jasper)

3.3 TYPES OF GUARDRAIL POST DRIVERS MEASURED

Each company used different post drivers. The machinery ranged from weight drop post drivers to vibratory post drivers to auger style post drivers. In Figures 3.2 and 3.3 a weight drop post driver is pictured. In Figures 3.4 and 3.5 a vibratory post driver is pictured. In Figures 3.6 and 3.7 an auger style post driver is pictured.

Figure 3.2: Weight drop post driver, Wheeler Road (Pleasant Hill)

Figure 3.3: Weight drop post driver with meters, Wheeler Road (Pleasant Hill)

Figure 3.4: Vibratory post driver, Old Brownsville Road (Brownsville)

Figure 3.5: Vibratory post driver close-up, Old Brownsville Road (Brownsville)

Figure 3.6: Auger style post driver close-up, Elkton-Sutherlin Highway (Elkton)

Figure 3.7: Auger style post driver, Elkton-Sutherlin Highway (Elkton)

3.4 LOCATION OF NOISE MEASUREMENTS

The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were taken 15 m from the guardrail post that was being driven. This is a standard distance of noise measurements from construction equipment. The sound level meter microphone was placed at a height of 1.5 m above the ground level of where the guardrail post was driven.

In addition, a continuous Leq/dBA measurement was taken at a fixed point 15 m from the line of posts during each operation.

3.5 SUMMARY OF NOISE MEASUREMENTS

Table 3.1 shows a summary of the guardrail installation noise measurements for the control site and four construction sites.

Table 3.1: Summary of Guardrail Installation Noise Measurements

Date	Location	Post Type (# Driven)	Post Driver Type	Average Leq/dBA (Range)	Average Lmax/dBA (Range)	Average L5 (Range)	Average L10 (Range)	Continuous Leq/dBA
-----Control Site-----								
8/27/98	Wheeler Road (Pleasant Hill)	Wood (25)	Weight drop Hammer	82 (80-84)	89 (86-91)	87 (85-89)	86 (84-88)	79
8/27/98	Wheeler Road (Pleasant Hill)	Steel (25)	Weight drop Hammer	82 (78-86)	89 (86-92)	87 (83-91)	86 (81-90)	77
-----Construction Sites-----								
10/27/98	Old Brownsville Road (Brownsville)	Steel (20)	Vibratory Hammer	91 (89-94)	94 (92-96)	94 (92-96)	93 (92-96)	87
10/29/98	Wallace Creek Road (Jasper)	Wood (12)	Weight drop Hammer	75 (70-78)	84 (79-86)	81 (77-83)	80 (75-82)	70
12/8/98	Country Club Road (Eugene)	Steel (24)	Vibratory Hammer	93 (87-95)	95 (89-98)	95 (89-97)	94 (89-97)	84
3/22/99	Elkton-Sutherlin Highway (Elkton)	Wood (25)	Auger/ Hydraulic Steel Slug	74 (72-75)	78 (74-81)	76 (73-78)	76 (73-77)	74

3.5.1 Comparison of Control Site Measurements

The comparison between driving wood posts and steel posts at the control site indicates little difference between measured noise levels. The post driver at the control site was a weight drop hammer. The post driving operation was smoother during the installation of wood posts than during the installation of steel posts. There were delays during the steel post installation for equipment adjustment. The smoother wood installation may have contributed to slightly higher overall continuous Leq/dBA levels when compared to installing steel posts at the control site due to longer idling periods during the installation of steel posts. All of the other noise parameters were very close for wood and steel.

3.5.2 Comparison of Wood Post Measurements

The comparison between driving wood posts at the construction sites and at the control site shows that noise levels were lower for post installation at the construction sites. The post driver at both the Wheeler Road (Pleasant Hill) control site and the Wallace Creek Road (Jasper) construction site was a weight drop hammer. The post driver at the Elkton-Sutherlin Highway (Elkton) construction site was an auger with a hydraulically operated steel slug. The average Leq/dBA noise levels were 7-8 dBA lower, and the average Lmax/dBA noise levels were 5-11 dBA lower at the construction sites. The continuous Leq/dBA noise levels were 5-9 dBA lower at the construction sites.

3.5.3 Comparison of Steel Post Measurements

The comparison between driving steel posts at construction sites and at the control site shows that noise levels were higher for post installation at the construction sites. The post driver at the construction sites was a vibratory hammer. The average Leq/dBA noise levels were 9-11 dBA higher, and the average Lmax/dBA noise levels were 5-6 dBA higher at the construction sites. The continuous Leq/dBA noise levels were 7-10 dBA higher at the construction sites.

3.5.4 Comparison of Overall Measurements

At the control site, the overall guardrail installation noise levels appear to be very similar between wood posts and steel posts. However, a comparison between wood and steel guardrail posts at the construction sites indicates that higher noise levels appear to be generated from installing steel posts. Higher noise levels were measured when a vibratory hammer, as compared to a weight drop hammer, accomplished the installation. Common construction practices indicate that wood guardrail posts are usually installed using a weight drop hammer and steel guardrail posts are usually installed with a vibratory hammer. Unfortunately, a vibratory hammer was not available for testing at the control site. The steel guardrail posts have a smaller cross sectional area than wood guardrail posts, so are easier to install with the vibratory hammer than wood posts. Overall ground conditions where the posts were driven seemed to be similar. However, the ground conditions at the Wallace Creek Road (Jasper) construction site, appeared to be less consolidated when compared to the other sites.

4.0 GUARDRAIL NOISE COMPARED TO PILE DRIVING NOISE

As summarized in Table 3.1, typical measured noise levels from guardrail installation measured for this study range from Lmax 74 dBA to Lmax 98 dBA.

Typical pile driving noise levels range from Lmax 93 dBA to Lmax 105 dBA. Currently, a noise level of Lmax 105 dBA is used for assessing noise impacts originating from *both* pile driving and guardrail installation operations. Other pile driving noise levels are summarized in Table 4.1. The Washington State Eagle Study noise measurements were taken at 30 m. These measurements are adjusted by the standard drop-off rate of six dBA per doubling of distance for comparison purposes in Table 4.1.

Table 4.1: Pile Driving Noise Levels

Source	Leq/dBA @ 15m	Lmax/dBA @ 15m	Notes
Washington State Eagle Study (1987)	84-90	93-98	Wood piles. Adjusted for distance.
Washington State Eagle Study (1987)	97	103	Steel piles. Adjusted for distance.
Boston Central Artery Project	--	90-100	Sheet pile driving measurements
17th St. Causeway Project, Ft. Lauderdale, FL	--	100-105	Sheet pile driving measurements
Construction Equipment Chart, Colorado Noise Symposium	--	95-**105**	Currently Lmax 105 dBA is used by ODOT biologists to determine noise levels from both pile driving and guardrail noise levels.

The highest measured noise levels are Lmax 98 dBA for guardrail installation at the control distance of 15 m. The highest typical noise levels for pile driving operations are Lmax 105 dBA. The highest typical Lmax noise levels for pile driving operations are 7 dBA higher than the highest measured Lmax noise levels for guardrail installation.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Based on the noise measurements conducted for several guardrail installations of both steel and wood posts, the highest measured noise levels are Lmax 98 dBA. The highest typical noise levels from pile driving operations were Lmax 105 dBA, and are 7 dBA higher than the highest measured Lmax noise levels for guardrail installation. Use of the highest typical noise levels from pile driving operations, for figuring guardrail installation noise, overestimates the noise level by approximately 7 dBA. Additionally, there is a significant difference in the height of the point source of noise between pile driving operations and guardrail post installation. Using the high-end noise level of Lmax 98 dBA for guardrail installation noise sources appears to be a reasonable approach to assessing noise from guardrail installation operations with the use of equipment that is similar to the equipment in this study.

The typical noise dropoff rate from a point source is six dBA per doubling of distance (six dBA/DD). This assumes that there are no site conditions present, such as extensive vegetation or terrain, that would further reduce noise levels from the point source. By using a noise level of Lmax 98 dBA for guardrail installation, instead of Lmax 105 dBA, now guardrail installation can take place in closer proximity (approximately half of the original distance) to areas with threatened and endangered species than before.

5.2 PERCEIVED BENEFITS

Even though restrictions on the guardrail installation process will not be eliminated due to these results, the following benefits should be realized:

- Potential increase in safety by permitting timely guardrail repair and installation in proximity to threatened and endangered species' sensitive areas
- Potential cost savings to the state by reducing contract time due to decreased multiple mobilization activities
- More prudent decisions at the biologist and project manager level

5.3 RECOMMENDATIONS

Since an attenuation model already exists, the results from this study may be immediately implemented by biologists in developing conservation measures for threatened and endangered species that may be affected by ODOT construction projects.

6.0 REFERENCES

Fundamentals and Abatement of Highway Traffic Noise. United States Department of Transportation, Federal Highway Administration. June 1973 (reprinted February 1979).

Fundamentals of Noise and Vehicle Exterior Noise Levels. Western Highway Institute. June 1971.

Noise Disturbance Study on Bald Eagles at Orcas and Shaw Island Ferry Terminals San Juan County, Washington. Washington State Department of Transportation. September 1987.

APPENDIX:

NOISE MEASUREMENT OF GUARDRAIL POST DRIVING

CONTROLLED SITE: WHEELER ROAD (PLEASANT HILL)

ODOT Environmental Services conducted noise measurements of guardrail post driving at the Wheeler Road stockpile site located northeast of Pleasant Hill. Ambient noise levels at this site were measured at a sound level equivalent of Leq 40 dBA on July 9, 1998, and Leq 42 dBA on August 27, 1998. This site was suitable for measuring guardrail post driving, as the ambient noise levels were fairly quiet, and did not create an additive effect to the measured noise levels during the guardrail post driving operations. The purpose of these measurements was to establish what noise levels are generated from the guardrail post driving under a relatively controlled environment, with the absence of substantial traffic or construction noise. The noise measurements were completed on August 27, 1998. Arno Nelson, Lane County Department of Public Works, supplied the equipment, posts, and labor for the measurements. The site is shown in Figure A.1.

Figure A.1: Wheeler Road (Pleasant Hill)

What Was Measured?

The equipment measured is a weight drop post driver, from DP Manufacturing, Tulsa OK, mounted on back of an L8000 Ford diesel pick-up. This is a smaller machine than the equipment contractors commonly use. The post driver weight is 795 kg, with dimensions of 0.3 m x 0.3 m x 1.1 m in height. Based on observations, the post driver weight is dropped to pound the post into the ground from an average height of approximately 1.5 m.

Where Were The Noise Measurements Taken?

Measurements were taken for driving wood posts and steel posts at the standard distances noted in Section 3.4. The posts were driven in a line approximately 18 m long, and approximately 1 m apart.

What Determined When Measurements Start And End?

Measurements started when the post driver engine was "revved" at the beginning of the post driving cycle. The measurements continued until the guardrail post was driven to a height of 0.7 m from the top of post to the ground (0.5 m from the ground to the top bolt hole, 0.2 m from the bolt hole to the top of post). Each post driven was considered a separate noise measurement. The time for a single post installation ranged from 30 to 90 seconds, with the number of blows ranging from 15 to 40. The elapsed time for a single blow was about 2 seconds.

Another operation suspected of having high noise levels was wrenching and bolting the guardrail together. The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were also made for this operation.

What Types and How Many Guardrail Post Installations Were Measured?

- Twenty-five 1.8 m Wood Guardrail Posts
- Twenty-five 2.4 m Metal I-Beam Posts

Noise Measurements and Observations – Wood Guardrail Posts

Noise measurements of wood guardrail posts were taken between 8:50 am and 9:47 am. During this time, a total of 25 wood guardrail posts were driven. Noise measurements were briefly stopped during this time to allow the operator to pull several posts out to re-use. These noise measurements are summarized in Table A.1.

The average Leq/dBA noise measurement during this operation was Leq 82 dBA. The average Lmax/dBA noise measurement was Lmax 89 dBA. The average L5 noise measurement was L5 87 dBA, and the average L10 noise measurement was L10 86 dBA. The continuous Leq/dBA noise measurement was Leq 79 dBA.

The post driving equipment worked quite smoothly during the installation of the wood guardrail posts, with a minimal amount of time used for adjusting equipment.

Table A.1: Wheeler Road (Pleasant Hill)-Wood Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	83	91	88	87	83
2	80	90	85	84	79
3	81	88	85	84	79
4	81	86	85	85	79
5	83	89	87	86	78
6	81	88	85	84	78
7	81	87	86	85	78
8	84	90	88	87	79
9	82	89	87	86	79
10	83	90	88	87	79
11	83	89	86	86	79
12	81	87	85	85	79
13	81	88	86	85	79
14	84	89	87	87	79
15	84	90	89	88	79
16	81	87	85	84	79
17	83	88	87	86	79
18	83	88	87	86	79
19	82	88	86	85	79
20	84	90	89	88	79
21	84	89	88	87	79
22	82	88	87	86	79
23	83	89	87	86	79
24	83	89	87	87	79
25	83	89	87	86	79
AVERAGE	**82**	**89**	**87**	**86**	**79**
RANGE	**80-84**	**86-91**	**85-89**	**84-88**	**--**

Noise Measurements and Observations – Steel Guardrail Posts

Noise measurements of steel guardrail posts were taken between 10:45 am and 11:42 am. During this time, a total of 25 steel guardrail posts were driven. None of these posts were re-used. These noise measurements are summarized in Table A.2.

The average Leq/dBA noise measurement during this operation was Leq 82 dBA. The average Lmax/dBA noise measurement was Lmax 89 dBA. The average L5 noise measurement was L5 87 dBA, and the average L10 noise measurement was L10 86 dBA. The continuous Leq/dBA noise measurement was Leq 77 dBA.

The post driving equipment did not appear to work as smoothly as during the installation of the wood guardrail posts. There were multiple delays during several of the steel posts being driven in order to adjust the equipment or the post. This resulted in longer idling time periods between post driving. The longer 2.4 m steel posts caused the post cover holding cable to catch, not releasing during the operation. Also, there seemed to be less ground vibration with the steel post installation than with the wood.

Table A.2: Wheeler Road (Pleasant Hill)-Steel Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	84	91	89	88	81
2	85	91	89	87	77
3	82	89	87	86	77
4	83	89	87	86	77
5	81	87	85	84	77
6	81	88	86	85	77
7	83	88	87	86	77
8	78	86	83	81	77
9	83	90	88	87	77
10	82	89	87	86	77
11	82	88	86	85	77
12	83	91	88	86	77
13	81	88	85	84	77
14	81	88	85	84	77
15	82	88	86	85	77
16	82	89	86	85	77
17	82	88	86	85	77
18	84	91	89	88	77
19	86	92	91	90	77
20	82	89	86	85	77
21	82	89	87	85	77
22	83	91	89	87	77
23	83	90	88	87	77
24	82	89	87	86	77
25	83	91	88	87	77
AVERAGE	**82**	**89**	**87**	**86**	**77**
RANGE	**78-86**	**86-92**	**83-91**	**81-90**	**--**

Noise Measurements and Observations – Bolting Guardrail

Noise measurements of bolting guardrail together with an air hammer were taken between 10:02 am and 10:05 am. These noise measurements are summarized in Table A.3.

The Leq/dBA noise measurement during this operation was Leq 76-77 dBA. The average Lmax/dBA noise measurement was Lmax 87 dBA. The average L5 noise measurement was L5 85 dBA, and the average L10 noise measurement was L10 83 dBA.

The measured noise levels indicate that the bolting of guardrail sections together generates high noise levels, but these noise levels are lower than the post driving operations of both wood and steel guardrail posts.

Table A.3: Wheeler Road (Pleasant Hill)-Bolting Guardrail Together with Air Hammer

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
Rail	77	87	85	83	76

Other Factors

Suitable weather conditions for noise measurements were present on the day of the guardrail post driving. Wind speeds were light, 5-10 mph from the north, with no rain occurring.

CONSTRUCTION SITE: OLD BROWNSVILLE ROAD (BROWNSVILLE)

ODOT Environmental Services conducted noise measurements of guardrail post driving at the Old Brownsville Road construction site located approximately 4 miles north of Brownsville. The purpose of these measurements was to establish typical noise levels generated from guardrail post driving under construction site conditions. The noise measurements were completed on October 27, 1998. The guardrail installation contractor was Dirt and Aggregate Interchange from Troutdale, Oregon. The site is shown in Figure A.2.

Figure A.2: Old Brownsville Road (Brownsville)

What Was Measured?

The equipment measured was a vibratory post driver, mounted on the back of a truck. Once the post was lined up for installation, the post driver used a reverberating fast-paced action to drive the post into the ground.

Where Were The Noise Measurements Taken?

The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were taken 15 m from the guardrail post that was being driven. This is a standard distance of noise measurements from construction equipment. Because the noise measurement site was at a lower elevation than the post driving location, the sound level meter microphone was

raised to a height of approximately 1.5 m above the ground level of where the guardrail post was driven. This was done to duplicate the control site measurement setup, and to minimize site factors that could affect the measurement. In addition, a continuous Leq/dBA measurement was taken at a fixed point at 15 m from the post line during the operation. Measurements were taken for driving steel posts. Measurements were taken when the posts were driven in a line approximately 36 m long, and approximately 2 m apart.

What Determined When Measurements Start And End?

Measurements started when the post and the post driver were aligned at the beginning of the post driving cycle. The measurements continued until the guardrail post was driven to a standard height. Each post driven was considered a separate noise measurement. Based on observations, the average driving time per post was approximately 20 seconds. The full cycle time from post to post was about 1 minute.

The Leq/dBA measurement at the fixed point was a continuous measurement during the entire operation. This included the post driving machine start up, post driving, and moving onto the next post to be driven, and continued through all the posts to be driven. This measurement captured the overall noise levels of the entire operation.

What Type and How Many Guardrail Post Installations Were Measured?

- Twenty 2 m Metal I-Beam Posts

Noise Measurements and Observations – Steel Guardrail Posts

Noise measurements of the steel guardrail posts were taken between 10:25 am and 10:45 am. During this time, a total of 20 steel guardrail posts were driven. These noise measurements are summarized in Table A.4.

The average Leq/dBA noise measurement during this operation was Leq 91 dBA. The average Lmax/dBA noise measurement was Lmax 94 dBA. The average L5 noise measurement was L5 94 dBA, and the average L10 noise measurement was L10 93 dBA. The continuous Leq/dBA noise measurement was Leq 87 dBA.

The post driving operation appeared to work quite smoothly, with no delays due to equipment or operators. One post of the twenty driven appeared to hit a rock, and took a longer driving time. There was no ground vibration noted at the measurement site during post driving.

A comparison of noise levels between this site and steel guardrail posts driven at the control site indicates that the Leq/dBA noise levels were 9 dBA higher, and the continuous Leq/dBA noise levels were 10 dBA higher. The Lmax/dBA noise levels were 5 dBA higher. The overall noise levels at this site were noticeably higher.

Table A.4: Old Brownsville Road (Brownsville)-Steel Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	91	94	93	93	88
2	91	94	94	94	85
3	93	95	95	95	84
4	91	93	92	92	84
5	90	93	93	93	84
6	89	93	93	92	84
7	90	93	93	93	84
8	89	93	93	92	85
9	90	94	93	93	85
10	89	92	92	92	85
11	91	96	96	95	86
12	89	93	93	93	85
13	94	96	96	96	86
14	91	93	92	92	86
15	92	95	94	93	86
16	90	93	93	93	86
17	93	95	94	94	87
18	91	95	95	94	87
19	90	94	93	93	87
20	92	95	95	95	87
AVERAGE	**91**	**94**	**94**	**93**	**87**
RANGE	**89-94**	**92-96**	**92-96**	**92-96**	**--**

Other Factors

Suitable weather conditions for noise measurements were present on the day of the guardrail post driving. Wind speeds were light, 10-15 mph from the south, and the site was protected from most of the wind from a hillside. Some light mist occurred for a short duration, but no rain was present.

CONSTRUCTION SITE: WALLACE CREEK ROAD (JASPER)

ODOT Environmental Services conducted noise measurements of guardrail post driving at the Wallace Creek Road construction site located approximately 2 miles east of Jasper. The purpose of these measurements was to establish typical noise levels generated from guardrail post driving under construction site conditions. These measurements would also be used to compare the wood guardrail post driving with the control site, as the equipment was the same. The noise measurements were completed on October 29, 1998. The guardrail installation contractor was Lane County. The site is shown in Figure A.3.

Figure A.3: Wallace Creek Road (Jasper)

What Was Measured?

The equipment measured is a post driver, from DP Manufacturing, Tulsa OK, mounted on back of an L8000 Ford diesel pick-up, and is the same equipment as used in the control site. The post driver weight is 1750 pounds, with dimensions of 0.3 m x 0.3 m x 1.1 m in height. Based on observations, the average height the post driver weight is dropped to pound the post into the ground is approximately 1.5 m.

Where Were The Noise Measurements Taken?

The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were taken 15 m from the guardrail post that was being driven. This is a standard distance of noise measurements from construction equipment. Because the noise measurement site was at a lower elevation than the post driving location, the sound level meter microphone was raised to a height of approximately 1.5 m above the ground level of where the guardrail post was driven. This was done to duplicate the control site measurement setup, and to minimize site factors that could affect the measurement. In addition, a continuous Leq/dBA measurement was taken at a fixed point at 15 m from the post line during the operation. Measurements were taken for driving wood posts.

What Determined When Measurements Start And End?

Measurements started when the post driver engine was “revved” at the beginning of the post driving cycle. The measurements continued until the guardrail post was driven to a standard height. Each post driven was considered a separate noise measurement. The time for a single post installation was approximately 1 minute, with the cycle time between posts about 3 minutes.

The Leq/dBA measurement at the fixed point was a continuous measurement during the entire operation. This included the post driving machine start up, revving, post driving, and moving onto the next post to be driven, and continued through all the posts located at 15 m distance from the measurement site. This was possible due to the guardrail line being adjacent to a roadway curve. This measurement captured the overall noise levels of the entire operation.

What Type and How Many Guardrail Post Installations Were Measured?

- Twelve 1.8 m Wood Guardrail Posts

Noise Measurements and Observations – Wood Guardrail Posts

Noise measurements of the wood guardrail posts were taken between 11:05 am and 11:45 am. During this time, a total of 12 wood guardrail posts were driven. These noise measurements are summarized in Table A.5.

The average Leq/dBA noise measurement during this operation was Leq 75 dBA. The average Lmax/dBA noise measurement was Lmax 84 dBA. The average L5 noise measurement was L5 81 dBA, and the average L10 noise measurement was L10 80 dBA. The continuous Leq/dBA noise measurement was Leq 70 dBA.

The post driving operation appeared to be affected by the site topography. The guardrail was located on a curve. In addition, the roadway was on a steep grade, making the operation slower, due to the frequent adjustment of the posts to the grade. Occasional aligning and bolting of the rail was being done at the same time, but no effect on the noise levels were noted. There was no ground vibration noted at the measurement site during post driving.

A comparison of noise levels between this site and wood guardrail posts driven at the control site indicates that the Leq/dBA noise levels were 7 dBA lower, and the continuous Leq/dBA noise levels were 9 dBA lower. The Lmax/dBA noise levels were 5 dBA lower. The Leq/dBA and the Lmax/dBA noise levels may have been lower at this site due to the posts being installed on fill material. The continuous Leq/dBA noise levels may have been lower at this site due to the longer adjustment period of the posts, as well as the posts being installed on fill material. Noise levels were lower at this site than on the control site.

Table A.5: Wallace Creek Road (Jasper)-Wood Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	76	86	82	81	77
2	72	79	77	76	72
3	78	84	83	82	72
4	76	84	81	80	72
5	77	85	82	81	72
6	75	84	81	80	72
7	70	82	77	75	72
8	76	84	82	80	71
9	76	86	82	81	71
10	75	83	80	79	70
11	76	83	81	80	71
12	75	84	80	79	70
AVERAGE	**75**	**84**	**81**	**80**	**70**
RANGE	**70-78**	**79-86**	**77-83**	**75-82**	**--**

Other Factors

Suitable weather conditions for noise measurements were present on the day of the guardrail post driving. Wind speeds were light, 0-5 mph from the west. No rain was present during the measurement period.

CONSTRUCTION SITE: COUNTRY CLUB ROAD (EUGENE)

ODOT Environmental Services conducted noise measurements of guardrail post driving at the Country Club Road off-ramp from eastbound Interstate 105 in Eugene. The purpose of these measurements was to establish typical noise levels generated from guardrail post driving under construction site conditions. The noise measurements were completed on December 8, 1998. The guardrail installation contractor was Coral Construction from Wilsonville, Oregon. The site is shown in Figure A.4.

Figure A.4: Country Club Road (Eugene)

What Was Measured?

The equipment measured was an Allied #730 vibratory post driver, mounted on the back of a truck. Once the post was lined up for installation, the post driver used a reverberating fast-paced action to drive the post into the ground.

Where Were The Noise Measurements Taken?

The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were taken 15 m from the guardrail post that was being driven. This is a standard distance of noise measurements from construction equipment. Because the noise measurement site was at a lower elevation than the post driving location, the sound level meter microphone was raised to a height of approximately 1.5 m above the ground level of where the guardrail post was driven. This was done to duplicate the control site measurement setup, and to minimize site factors that could affect the measurement. In addition, a continuous Leq/dBA measurement was taken at a fixed point at 15 m from the post line during the operation. Measurements were taken for driving steel posts. Measurements were taken when the posts were driven in a line approximately 45 m long, and approximately 2 m apart.

What Determined When Measurements Start And End?

Measurements started when the post and the post driver were aligned at the beginning of the post driving cycle. The measurements continued until the guardrail post was driven to a standard height. Each post driven was considered a separate noise measurement. Based on observations, the average driving time per post was approximately 1 minute. The full cycle time from post to post was about 2 minutes.

The Leq/dBA measurement at the fixed point was a continuous measurement during the entire operation. This included the post driving machine start up, post driving, and moving onto the next post to be driven, and continued through all the posts to be driven. This measurement captured the overall noise levels of the entire operation.

What Type and How Many Guardrail Post Installations Were Measured?

- Twenty-four 2 m Metal I-Beam Posts

Noise Measurements and Observations – Steel Guardrail Posts

Noise measurements of the steel guardrail posts were taken between 1:30 pm and 3:00 pm. During this time, a total of 24 steel guardrail posts were driven. These noise measurements are summarized in Table A.6.

The average Leq/dBA noise measurement during this operation was Leq 93 dBA. The average Lmax/dBA noise measurement was Lmax 95 dBA. The average L5 noise measurement was L5 95 dBA, and the average L10 noise measurement was L10 94 dBA. The continuous Leq/dBA noise measurement was Leq 84 dBA.

The post driving operation was not continuous for the entire run. Moving of a GM concrete barrier temporarily halted the operation. There were a couple of equipment delays during the noise measurements that may have contributed to some of the variability in the continuous Leq/dBA noise measurement. When the posts were being driven, the operation progressed along quite rapidly. There was no ground vibration noted at the measurement site during post driving.

A comparison of noise levels between this site and steel guardrail posts driven at the control site indicates that the Leq/dBA noise levels were 11 dBA higher, and the continuous Leq/dBA noise levels were 7 dBA higher. The Lmax/dBA noise levels were 6 dBA higher. The overall noise levels at this site were noticeably higher.

A comparison of noise levels between this site and steel guardrail posts driven at the Old Brownsville Road, near Brownsville construction site indicates that the noise levels were quite comparable, with noise levels about 1 to 2 dBA higher at this site. The continuous Leq/dBA noise levels were slightly lower, being 3 dBA less at this site. Equipment delays likely contributed to the slightly lower continuous Leq/dBA noise levels.

Table A.6: Country Club Road (Eugene)-Steel Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	87	89	89	89	84
2	92	94	94	94	82
3	91	94	93	93	82
4	93	95	95	94	89
5	92	95	94	94	84
6	91	93	93	93	84
7	95	97	97	96	85
8	95	98	97	96	86
9	94	96	95	95	86
10	90	93	92	92	86
11	92	95	94	93	86
12	91	94	93	93	86
13	91	93	93	93	86
14	93	96	96	95	86
15	95	97	97	97	85
16	94	96	95	95	85
17	91	95	95	94	85
18	93	96	95	95	85
19	95	97	96	96	85
20	94	97	96	95	85
21	93	96	96	95	84
22	94	96	95	95	84
23	91	95	94	94	84
24	93	95	95	95	84
AVERAGE	**93**	**95**	**95**	**94**	**84**
RANGE	**87-95**	**89-98**	**89-97**	**89-97**	**--**

Other Factors

Suitable weather conditions for noise measurements were present on the day of the guardrail post driving. Wind speeds were calm, and the weather was partly sunny with no rain.

CONSTRUCTION SITE: ELKTON-SUTHERLIN HIGHWAY (ELKTON)

ODOT Environmental Services conducted noise measurements of guardrail post driving on the Elkton-Sutherlin Highway, approximately one mile southeast of Elkton. The purpose of these measurements was to establish typical noise levels generated from guardrail post driving under construction site conditions. The noise measurements were completed on March 22, 1999. The guardrail installation contractor was Coral Construction from Wilsonville, Oregon. The site is shown in Figure A.5.

Figure A.5: Elkton-Sutherlin Highway (Elkton)

What Was Measured?

The equipment measured was a Texoma 500 Auger with a hydraulically operated steel slug (1130 kg), mounted on the back of a truck. The post hole was first started with a metal driver, and the post was later placed into the machine and driven into the ground with a weight drop hammer. Both the metal driver and the post were enclosed within a metal surround.

Where Were The Noise Measurements Taken?

The Leq/dBA, Lmax/dBA (A scale), L5 and L10 noise measurements were taken 15 m from the guardrail post that was being driven. This is a standard distance of noise measurements from construction equipment. Because the noise measurement site was at a lower elevation than the post driving location, the sound level meter microphone was raised to a height of approximately 1.5 m above the ground level of where the guardrail post was driven. This was done to duplicate the control site measurement setup, and to minimize site factors that could affect the measurement. In addition, a continuous Leq/dBA measurement was taken at a fixed point at 15 m from the post line during the operation. Measurements were taken for driving wood posts. Measurements were taken when the posts were driven in a line approximately 45 m long, and approximately 2 m apart.

What Determined When Measurements Start And End?

Measurements started when the post and the post driver were aligned at the beginning of the post driving cycle. The measurements continued until the guardrail post was driven to a standard height. Each post driven was considered a separate noise measurement. Based on observations, the average driving time per post was approximately 1 minute. The full cycle time from post to post was about 2 minutes.

The Leq/dBA measurement at the fixed point was a continuous measurement during the entire operation. This included the post driving machine start up, post driving, and moving onto the next post to be driven, and continued through all the posts to be driven. This measurement captured the overall noise levels of the entire operation.

What Type and How Many Guardrail Post Installations Were Measured?

- Twenty-five 1.8 m Wood Guardrail Posts

Noise Measurements and Observations – Wood Guardrail Posts

Noise measurements of the wood guardrail posts were taken between 11:00 am and 11:30 am. During this time, a total of 25 wood guardrail posts were driven. These noise measurements are summarized in Table A.7.

The average Leq/dBA noise measurement during this operation was Leq 74 dBA. The average Lmax/dBA noise measurement was Lmax 78 dBA. The average L5 noise measurement was L5 76 dBA, and the average L10 noise measurement was L10 76 dBA. The continuous Leq/dBA noise measurement was Leq 74 dBA.

The post driving operation went very smoothly, and when the posts were being driven, the operation progressed along quite rapidly. There was no ground vibration noted at the measurement site during post driving.

A comparison of noise levels between this site and wood guardrail posts driven at the control site indicates that the Leq/dBA noise levels were 8 dBA lower, and the continuous Leq/dBA noise levels were 5 dBA lower. The Lmax/dBA noise levels were 11 dBA lower. The overall noise levels at this site were noticeably lower.

A comparison of noise levels between this site and wood guardrail posts driven at the Wallace Creek Road (Jasper) construction site indicates that the noise levels were slightly lower, except for the continuous Leq/dBA noise levels. Most of the noise levels were 1 to 6 dBA lower at this site. The continuous Leq/dBA noise levels were slightly higher, being 4 dBA greater at this site. There were no equipment delays at this site, which likely contributed to the slightly higher continuous Leq/dBA noise levels.

Table A.7: Elkton-Sutherlin Highway (Elkton)-Wood Guardrail Posts

Post Number	Leq/dBA	Lmax/dBA	L5	L10	Continuous Leq/dBA
1	72	74	73	73	68
2	75	78	77	77	70
3	75	79	78	77	71
4	74	78	76	76	71
5	74	78	77	77	72
6	73	77	76	75	72
7	73	78	76	76	72
8	74	77	76	76	73
9	73	78	76	75	73
10	74	77	76	75	73
11	74	77	76	76	73
12	74	77	76	75	73
13	74	77	76	76	73
14	74	79	76	76	73
15	74	77	76	76	73
16	74	77	76	75	73
17	75	78	77	76	73
18	74	78	76	75	73
19	75	81	78	77	73
20	74	78	76	76	74
21	74	78	76	76	74
22	74	78	76	76	74
23	74	79	77	76	74
24	75	79	77	77	74
25	74	77	76	76	74
AVERAGE	**74**	**78**	**76**	**76**	**74**
RANGE	**72-75**	**74-81**	**73-78**	**73-77**	**--**

Other Factors

Suitable weather conditions for noise measurements were present on the day of the guardrail post driving. Wind speeds were calm, and the weather was partly sunny.