SCDA-80

Washington State Department of Transportation

WSDOT Biological Assessment Guidance

- WSDOT BA Preparation Manual
- Species Habitat Assessment and Effect Determination Guidance
- Stormwater Guidance
- Noise Assessments

If you would like to receive email updates when biological assessment guidance is added or updated, please sign up for our BA Authors list (A list for people who prepare biological assessments).

Biological Assessment Preparation for Transportation Projects - Advanced Training Manual

Part 1 - General Information for BA Authors

- Ch. 1 Introduction (pdf 269 kb) Feb 2015
- Ch. 2 Understanding the Biological Assessment Process (pdf 449 kb) Feb 2015
- Ch. 3 Components of a Biological Assessment (pdf 457 kb) Feb 2015

Part 2 - Guidance on Specific BA Topics

- Ch. 4 Components of a Biological Opinion (pdf 243 kb) Feb 2015
- Ch. 5 Endangered Species Act and Mitigation (pdf 226 kb) Feb 2015
- Ch. 6 Impact Avoidance and Minimization Measures (pdf 601 kb) July 2017
- Ch. 7 Noise Impact Assessment (pdf 1.8 mb) Apr 2017
    - Thresholds
    - Spreadsheets
    - Pile Driving Information
- Ch. 8 Action Area (pdf 821 kb) Feb 2015
- Ch. 9 Environmental Setting within the Action Area (pdf 453 kb) Feb 2015
- Ch. 10 Indirect Effects (pdf 733 kb) Feb 2015
- Ch. 11 Cumulative Effects (pdf 225 kb) Feb 2015
- Ch. 12 Effect Determination Language (pdf 477 kb) Feb 2015
- Ch. 13 Effect Determination Guidance (pdf 456 kb) Nov 2015
- Ch. 14 In-Water Work (pdf 296 kb) Feb 2015
- Ch. 15 Performance-Based, Batched, and Programmatic Biological Assessments (pdf 165 kb) Sept 2015
- Ch. 16 Essential Fish Habitat (pdf 450 kb) Feb 2015
- Ch. 17 Stormwater Impact Assessment (pdf 885 kb) Feb 2015
    - Eastern Washington Stormwater Guidance
    - Western Washington Stormwater Assessment Guidance: HI-RUN
    - Programmatic Stormwater Monitoring Approach
    - Indirect Effects Stormwater Runoff Analytical Method

Part 3 - Additional Resources for BA Authors

- Ch. 18 Gathering Information for a Biological Assessment (pdf 230 kb) Feb 2015

- Ch. 19 Information on Listed Species (pdf 560 kb) Nov 2016
- Ch. 20 References (pdf 264 kb) Apr 2017
- Ch. 21 Glossary and Abbreviations (pdf 182 kb) Feb 2015

Species Habitat Assessment and Effect Determination Guidance

Marbled Murrelet
The marbled murrelet nesting season in Washington is defined as the period from April 1 to September 23. USFWS typically requires the limited operating period (LOP) of two hours after sunrise to two hours before sunset to facilitate murrelet protection during the nesting season.

The USFWS definition of marbled murrelet nesting habitat is based on the presence of potential nest platforms. A site is considered to have suitable nesting habitat if a platform tree is within a minimum 5-acre contiguous coniferous-dominated stand within the project analysis area, has trees that are greater than or equal to 15 inches dbh, and has any platform that is a minimum of 4 inches wide a minimum of 33 feet above the ground. Work within or adjacent to marbled murrelet habitat during the nesting season may only occur during the LOP - two hours after sunrise to two hours before sunset.

- Marbled Murrelet Nesting Season and Analytical Framework for Section 7 Consultation in Washington (pdf 828 kb) - June 2012
- Guidance for Identifying Marbled Murrelet Nest Trees in Washington State (pdf 386 kb) - April 2012

In 2015, the USFWS issued a programmatic Biological Opinion (BO) for WSDOT activities. The BO establishes harassment/injury distances for noise-generating activities specific to marbled murrelets that replaces the 92 dBA threshold with the distance threshold. The standard threshold distances described in the BO can be used as a tool to assist the biologist in making effect determinations on typical transportation projects in Washington State.

- Marbled Murrelet Site Evaluation and Effect Determination Guidance (pdf 786 kb)

Northern Spotted Owl
In 2015, the USFWS issued a programmatic Biological Opinion for WSDOT activities. The BO establishes harassment/injury distances for noise-generating activities specific to northern spotted owls that replaces the 92 dBA threshold with the distance threshold. The standard threshold distances described in the BO can be used as a tool to assist the biologist in making effect determinations on typical transportation projects in Washington State.

- Spotted Owl Site Evaluation and Effect Determination Guidance (pdf 1.2 mb)

Oregon Spotted Frog
In 2015, the USFWS issued a programmatic Biological Opinion for WSDOT activities. The BO includes habitat suitability assessment guidance for Oregon spotted frog. The guidance provided in the BO can be used as a tool to assist the biologist in making Oregon spotted frog effect determinations on typical transportation projects in Washington State.

- Oregon Spotted Frog and Critical Habitat Presence Assessment (pdf 58 kb)
- Draft Oregon Spotted Frog Area of Influence (pdf 1.5 mb)

Listed Plants Consultations
WSDOT has developed this brief guidance (pdf 27 kb) to facilitate consultations related to listed plants. For help on identification of plant species and their habitats, the Washington State Department of Natural Resources' Natural Heritage Program and the Spokane District of the USDI Bureau of Land Management prepared a Field Guide to Selected Rare Plants of Washington.

Marine Mammal ESA Consultations
The National Marine Fisheries Service Marine Mammals Section 7 Consultation tools explain the relationship between the Endangered Species Act and the Marine Mammal Protection Act, effects of noise on marine mammals, sound threshold guidance, and other related topics. In 2016, NMFS introduced revised acoustical technical guidance.

Stormwater Guidance
On February 16, 2009, the Federal Highway Administration (FHWA), National Marine Fisheries Service

(NMFS), United States Fish & Wildlife Service (USFWS) and the Washington State Department of Transportation (WSDOT) signed a Memorandum of Agreement (MOA) (pdf 130 kb) committing these four agencies to use a common method for analyzing the effects of stormwater on Endangered Species Act (ESA)-listed fish species. The method includes the Western Washington Highway Runoff Dilution and Loading Stormwater Model (HI-RUN Model), its user guide, and accompanying stormwater assessment guidance that is posted below. A Stormwater Impact Assessment Chapter has been incorporated into Part 3 of the WSDOT Biological Assessment Preparation for Transportation, Advanced Training Manual.

The approach is required in all biological assessments submitted by WSDOT or WSDOT Local Programs.

Note that there is a separate assessment process for Eastern Washington that does not involve the use of the HI-RUN model. Also to Note, the HI-RUN Model User's Guide and Stormwater Chapter were all updates in January 2011. Be sure you are using the most recent version.

Eastern Washington Stormwater Guidance

- Stormwater Water Quality Analysis Process for Eastern Washington-Flowchart and Guidance (pdf 53 kb) - January 27, 2009
- Highway Runoff Manual Endangered Species Act Stormwater Design Checklist for Eastern Washington (doc 119 kb) - January 2010

Western Washington Stormwater Assessment Guidance
The HI-RUN Model should only be used for stormwater analysis associated with biological assessments, and should not be used as a design tool.

- HI-RUN Questions & Answers (pdf 57 kb) - June 2011
- HI-RUN Step-by-Step Example (pdf 1.75 mb) June 2011
- HI-RUN Model v. 2.0 (Excel 3.2 mb) - use with Office 2010
- HI-RUN Model v. 2.1 (Excel 2.0 mb) - use with Office 2013
- HI-RUN Model User's Guide (pdf 2.1 mb) - February 2011
- HI-RUN User's Input/Output Guide (pdf 322 kb) - March 2010
- HI-RUN Dilution and Loading Model Documentation (pdf 2.7 mb) - January, 2009
- RIVPLUM Validation Study (pdf 2.4 mb) - September 2009

Examples for Using the HI-RUN Model

- Example - Inputs for HI-RUN Model End-of-Pipe Loading Subroutine (pdf 219 kb) - April 2009
- Example - Illustration of ESA Stormwater Effects Evaluation using Western Washington Stormwater Checklist (pdf 578 kb) - April 2009

Endangered Species Act Stormwater Design Checklist for Western Washington (doc 162 kb) - January 2010

*Please download to your computer prior to use. Please contact Marion Carey, if you encounter problems or errors when using the HI-RUN Model.

Programmatic Stormwater Monitoring Approach
This approach focuses on utilizing the WSDOT NPDES permit monitoring requirements to meet stormwater monitoring needs rather than monitoring individual projects. The compiled data will be used to improve the accuracy and reliability of the current stormwater models. FHWA-funded local agency projects that are similar in scope to WSDOT projects and meet or exceed the requirements of the Highway Runoff Manual for stormwater treatment may also be able to utilize this approach.

- Programmatic Monitoring Approach for Highway Stormwater Runoff in Support of Endangered Species Act (ESA) Section 7 Consultation (pdf 54 kb) - January 2010

top

Indirect Effects Stormwater Runoff Analytical Method
On April 14, 2011, WSDOT, FHWA, NOAA Fisheries , USFWS and WSDOT signed a MOA committing these four agencies to use the Indirect Effects Stormwater Runoff Analytical Method in consultations which have development identified as in indirect effect of a transportation project. This analytical method is intended to evaluate water quality impacts associated with stormwater runoff from development identified as an indirect

effect of transportation projects.

- Indirect Effects Stormwater Runoff Analytical Method Memo (pdf 60 kb)
- Indirect Effects Stormwater Runoff Analytical Method Agreement Letter (pdf 58 kb)

Noise Assessment Guidance

Thresholds
The tables below provide summary information on marine mammal, fish, and marbled murrelet injury and disturbance thresholds for impulsive and continuous underwater sound, and estimated auditory bandwidths (estimated hearing frequency ranges) for marine mammals and fish.

- Marine Mammal and Fish Injury and Disturbance Thresholds for Underwater Construction Activity (pdf 21 kb) - September 2016
- Marbled Murrelet Effects Thresholds (pdf 73 kb) - February 2014
- Estimated Auditory Bandwidths for Marine Mammals and Fish (pdf 228 kb) - December 2016
- Interim Criteria for Injury to Fish (pdf 793 kb)

On November 19, 2013, WSDOT hosted a USFWS presentation that introduced marbled murrelet in-air noise masking guidance for marine water pile driving projects. The USFWS is using this guidance in marine pile driving consultations.

- Marbled Murrelet Masking Analysis (pdf 4.46 mb) - November 2013

Spreadsheets

- NMFS Spreadsheet Fish (excel 47 kb)
- NMFS Spreadsheet Marine Mammals (excel 28 kb) Sept 2016

USFWS has created an excel spreadsheet that assists in calculating distances to thresholds.

- Murrelet and Bull Trout Threshold Spreadsheet March 3 2014 (excel 37 kb)

Pile Driving Information
The tables below provide information on the typical number of pile strikes for steel piles, peak sound pressure levels and sound exposure levels for various sizes and types of piles. The data in these tables can be used to estimate sound pressure and cumulative sound exposure levels (SELcum) for various pile diameters and types. WSDOT Pile driving monitoring reports can help with site specific information for projects in the same or similar areas. The link to the CalTrans Pile Driving Compendium is also provided for comparison.

- Pile Strike Summary Tables (pdf 35 kb)
- Pile Diameter and Noise Levels (pdf 218 kb) - Sept 2016
- Airborne Vibratory Noise Information (pdf 936) - June 2010
- Airborne Sound Levels for Impact Driving (pdf 178kb)

Additional Acoustical Resources

- CalTrans Fisheries - Bioacoustics
- NOAA Marine Mammal Acoustic Technical Guidance - September 2016
- NOAA Fisheries Acoustics Program
- NOAA Fisheries Ocean Acoustics
- Sound in the Sea
- NOAA's Underwater Acoustics Tutorial
- Greeneridge Sciences, Inc.

Terrestrial Noise Assessment
Use the information in Chapter 7 of the BA Preparation for Transportation Projects Advance Training manual to help determine the appropriate decibel levels for ambient noise, traffic noise and construction noise.

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7.0 Construction Noise Impact Assessment

Contents

Tables

Figures

Table 7-4 (continued). Average maximum noise levels at 50 feet from common construction equipment.

Equipment Description	Impact Device?	Actual Measured Average L_{max}[b] at 50 feet
Roller	No	80
Sand Blasting (Single Nozzle)	No	96
Scraper	No	84
Shears (on backhoe)	No	96
Slurry Plant	No	78
Slurry Trenching Machine	No	80
Tractor [a]	No	84
Vacuum Excavator (Vac-truck)	No	85
Vacuum Street Sweeper	No	82
Ventilation Fan	No	79
Vibrating Hopper	No	87
Vibratory Concrete Mixer	No	80
Vibratory Pile Driver	No	101
Warning Horn	No	83
Water Jet Deleading	No	92
Welder / Torch	No	74

[a] Construction Noise Handbook (FHWA 2006)

[b] L_{max} is the maximum value of a noise level that occurs during a single event.

7.1.3.2 Stationary Equipment

Stationary equipment such as pumps, power generators, and air compressors generally run continuously at relatively constant power and speeds. Noise levels at 50 feet from stationary equipment can range from 68 to 88 dBA, with pumps typically in the quieter range. The biologist can also assume an averaged noise level for stationary equipment because of its fixed location and constant noise pattern.

7.1.3.3 Impact Equipment

Impact equipment includes pile drivers, jackhammers, pavement breakers, rock drills, and other pneumatic tools where a tool bit touches the work. The noise from jackhammers, breakers, rock drills, and pneumatic tools comes from the impact of the tool against material. These levels can vary depending on the type and condition of the material. Noise levels at 50 feet from impact equipment, including pile drivers, jackhammers, and rock drills can range from 79 to 110 dBA. Blasting may be associated with impact equipment use and that noise can reach 126 dBA.

An impact pile-driving hammer is a large piston-like device that is usually attached to a crane. The power source for impact hammers may be mechanical (drop hammer), air steam, diesel, or hydraulic.

Most impact pile driver hammers have a vertical support that holds the pile in place, and a heavy weight, or ram, moves up and down, striking an anvil that transmits the blow of the ram to the pile. In hydraulic hammers, the ram is lifted by fluid, and gravity alone acts on the down stroke.

A diesel hammer, or internal combustion hammer, carries its own power source and can be open-end or closed-end. An open-end diesel hammer falls under the action of gravity alone. A closed-end diesel hammer (double-acting) compresses air on its upward stroke and therefore can operate faster than open-end hammers.

Vibratory pile driver hammers are also used on projects. A vibratory pile-driving hammer has a set of jaws that clamp onto the top of the pile. The pile is held steady while the hammer vibrates the pile to the desired depth. Because vibratory hammers are not impact tools, noise levels are typically not as high as with impact pile drivers. However, piles installed with a vibratory hammer must often be proofed, which involves striking the pile with an impact hammer to determine its load-bearing capacity, possibly with multiple impacts. The project biologist should check with the design engineer to determine if impact driving or proofing of the piles will be needed. If so, the project biologist should include proofing noise from impact pile driving in the assessment.

Although stationary equipment noise and heavy equipment noise can be averaged over a period of time, impact pile driving noise consists of a series of peak events. Generally, noise from impact pile driving is reported at maximum levels. The loudest in-air noise from impact pile driving results from the impact of the hammer dropping on the pile, particularly when hollow steel piles are used. Though noise levels are variable during pile driving, to be conservative (more protective of the listed species), the project biologist should assume that noise at the highest levels documented is generated by impact pile driving and should avoid using an average in a noise assessment.

When conducting an in-air noise assessment involving impact driving of hollow steel piles, USFWS currently recommends assuming a noise level of 115 dBA L_{max} at 50 feet (for 30-inch piles) (Visconty 2000) as a worst-case scenario, where L_{max} is the maximum value of a noise level that occurs during a single event. Most of the documented studies have maximum decibel levels between 95 and 115 dBA, with only one documented level above 115 dBA. Noise assessments by WSDOT have documented maximum levels of 103 dBA L_{max} for 24-inch piles and 110 dB L_{max} for 30-inch piles each measured at a range of 11 meters (Illingworth and Rodkin 2010). If site-specific information is available, or smaller diameter piles are used, it may be appropriate to substitute lower values.

When assessing in-air noise for pinnipeds, un-weighted Root Mean Square (RMS) sound level should be used to compare to the un-weighted RMS threshold values. Assessments by WSDOT have documented un-weighted RMS levels for a vibratory hammer to be between 88 dB (18-inch pile) and 98 dB (30-inch pile) at 50 feet (Laughlin 2010b). Un-weighted RMS impact hammer in-air sound levels were between 98 dB and 102 dB at 50 feet for 72-inch piles (Laughlin 2011).

Table 7-17. Noise reduction values for all Washington State DOT projects from 2005 to 2009 for steel piles of different diameters using an <u>unconfined</u> bubble curtain.

Location	Pile Diameter (inches)	Substrate Type	Hammer Energy Rating (ft-lbs) [a]	Date	Pile #	Average Noise Reduction per Pile (dB)
Friday Harbor Ferry Terminal	24	Silty sand with hard clay layer	60,000	2/10/05	1	5
				2/23/05	4	0
				2/24/05	5	1
	30	Silty sand with hard clay layer	60,000	3/4/05	8	3
Bainbridge Island Ferry Terminal	24	Sand and Fist-sized rocks to 1-foot rocks	55,000	10/18/05	1	14
					2	10
				10/20/05	3	7
					4	3
					5	3
Cape Disappointment Boat Launch Facility [b]	12	Silt and mud with glacial till layer	52,000	12/13/05	1	6
				12/14/05	2	14
					3	11
					4	17
					5	6
Mukilteo Test Pile Project	36	Sand and silt	164,000	11/16/06	R2	7
					T2	22
Anacortes Ferry Terminal	36	Sand and Silt Mix	165,000	1/17/07	1	11
					2	11
				1/19/07	4	5
					5	10
					6	8
					7	3
					8	9
SR 520 Test Pile Project	24	Very loose unconsolidated silt overlying glacial till	20,100	10/27/09	PB-1	11
					PB-2	3
					PB-3	26
					PB-4	28
	30			10/29/09	WAB2	32
					WAB5	19

Table 7-17 (continued). Noise reduction values for all Washington State DOT projects from 2005 to 2009 for steel piles of different diameters using an unconfined bubble curtain.

Location	Pile Diameter (inches)	Substrate Type	Hammer Energy Rating (ft-lbs) [1]	Date	Pile #	Average Noise Reduction per Pile (dB)
SR 529 Ebey Slough Bridge Replacement Project	72	Deep loamy silt	327,222	1/6/11	4	16
					5	22
				1/11/11	3	24
					6	26

[a] Actual energy used during operation of impact hammer is approximately 50% to 70% of this maximum energy for most piles. All hammers are diesel.

[b] These piles had steel wings that linked the piles together and pile caps were used between the pile and the hammer which possibly increased the number of total strikes per pile.

Table 7-18. Noise reduction values for all Washington State DOT projects from 2005 to 2009 for steel piles of different diameters using a confined bubble curtain.

Location	Pile Diameter (inches)	Substrate Type	Hammer Energy Rating (ft-lbs)	Date	Pile #	Average Noise Reduction per Pile (dB)
SR 24 – Yakima River	24	Large 1-to 3-foot diameter boulders (riprap) with river rock and gravel below	60,000	6/7/05	3	0
				6/14/05	5	5
					:	
Eagle Harbor Maintenance Facility	24	unknown	164,000	10/31/05	1	7
					3	4
SR 411 Cowlitz River	24	Silty Sand	72,900	7 – 8/ 2006	4	8
					7	4
					8	9
SR 520 Test Pile Project	30	Very loose unconsolidated silt overlying glacial till	20,100	10/29/09	WAB1	38
					WAB4	34

[a] Actual energy used during operation of impact hammer is approximately 50% to 70% of this maximum energy for most piles. All hammers are diesel.

Table 7-19. Noise reduction values for all Washington State DOT projects from 2006 to 2009 for steel piles of different diameters using a <u>Temporary or Double Walled Noise Attenuation Pile (TNAP or DNAP)</u>.

Location	Pile Diameter (inches)	Substrate Type	Hammer Energy Rating (ft-lbs) [a]	Date	Pile #	Average Noise Reduction per Pile (dB)
Mukilteo Test Pile Project (TNAP1) [b]	36	Sand and silt	164,000	11/16/06	R4	7
				2/19/07		15
Mukilteo Test Pile Project (TNAP2) [c]	36	Sand and silt	164,000	11/16/06	R3	21
					R1	17
SR 520 Test Pile Project (DNAP) [d]	30	Very loose unconsolidated silt overlying glacial till	20,100	10/29/09	WAB3	11
Vashon Test Pile Project (modified TNAP) [e]	30	Silty Sand	164,620	11/17/09	P-14	9
					P-10	9
				11/18/09	P-16	13
					P-8	12

[a] Actual energy used during operation of hammer is approximately 50% to 70% of this maximum energy for most piles. All hammers are diesel.

[b] TNAP1 (Temporary Noise Attenuation Pile) is a hollow walled steel pile casing placed around the pile being driven. Hollow cavity accidentally filled with water during installation, thus substantially reducing its potential effectiveness. The TNAP1 was repaired and retested on 2/19/07.

[c] TNAP2 is a steel pile with a 2-inch thick closed cell foam lining on the inside of the pile and a perforated metal screen on the inside of the foam.

[d] DNAP is a steel casing with a 1-inch air space and 4 inches of insulation and an inner steel casing sealed together at the top and bottom.

[e] Modified TNAP is a hollow steel casing with a 2-inch foam-filled hollow wall and a bubble ring on the inside at the bottom but only sealed at the bottom.

Impact driving in the dry can also generate underwater noise in adjacent aquatic habitats. Sound flanking occurs when a pressure wave travels down the pile, is transmitted into the soil, and then travels back up through the soil and into the water column. Pile driving in the dry is a minimization measure designed to reduce the amount of sound that is transmitted through the water. Currently, we have an approved method for calculating transmission loss from pile driving in the air and a method for calculating transmission loss from pile driving in the water. There is no method for calculating transmission loss through soil outside of the water, and then calculating the loss in the water. What we don’t know is how much transmission loss occurs within the soil – the assumption is that it is greater than what occurs in water or air due to the denseness of the soil. We know that soil type - density and composition can affect transmission loss. It is impossible to predict what the transmission loss in soil will be and what the sound level will be at when it enters the water column. We have monitored a very few piles that have been driven in the dry; adjacent to or within the OHWM of a river. This includes H-piles, 16-inch steel and 72-inch steel piles. In all cases the pile installation did not exceed the current

Airborne Sound levels for Impact Driving (A-weighted, dBA)

Date	Pile Size (inches)	Location	Distance (ft)	Measured Leq (dBA)	Leq at 50 ft. (dBA)	Measured Lmax (dBA)	Lmax at 50 ft. (dBA	Hammer Size/Type
12/14/2005[1]	12	Cape Disappointment	164	N/A	N/A	89	99	Vulcan Air Hammer
11/14/2006[2]	36, w/ 1 inch wall	Mukilteo Ferry Terminal	300	87	95	97	112	N/A
11/16/2006[2]	36, double wall TNAP	Mukilteo Ferry Terminal	300	86	94	93	109	N/A
11/16/2006[2]	36, foam lined TNAP	Mukilteo Ferry Terminal	300	85	93	94	110	N/A
11/16/2006[2]	36 , w/ 1 inch wall and no bubble curtain	Mukilteo Ferry Terminal	300	97	105	95	110	N/A
12/5/2006[2]	36, hollow concrete	Mukilteo Ferry Terminal	300	93	101	98	114	N/A
12/5/2006[2]	36, hollow concrete	Mukilteo Ferry Terminal	300	86	94	95	110	N/A
11/14/2006[2]	36, double wall TNAP	Mukilteo Ferry Terminal	320	N/A	N/A	88	104	N/A
11/14/2006[2]	36, w/ 1 inch wall	Mukilteo Ferry Terminal	320	87	95	97	113	N/A
12/5/2006[2]	36 inch hollow concrete	Mukilteo Ferry Terminal	320	87	95	94	110	N/A
10/27/2010[3]	24 inch	SR 520 Test Pile	410	74	92	81	99	MHU 500T/ MHU 1700T
10/27/2010[3]	24 inch w/ noise blanket	SR 520 Test Pile	410	74	92	58	76	MHU 500T/ MHU 1700T

Date	Pile Size (inches)	Location	Distance (ft)	Measured Leq (dBA)	Leq at 50 ft. (dBA)	Measured Lmax (dBA)	Lmax at 50 ft. (dBA	Hammer Size/Type
10/6/2015[4]	24 inch	Vashon Ferry Terminal	43	96	95	109	108	N/A
12/7/2015[4]	30 inch	Vashon Ferry Terminal	66	93	95	108	110	N/A
12/7/2015[4]	30 inch Double Walled	Vashon Ferry Terminal	66	98	100	109	111	N/A
2/2/2016[5]	36 inch steel	Colman Dock	75	93	97	110	114	N/A
2/3/2016[5]	36 inch hollow concrete	Colman Dock	33	98	94	114	110	N/A
2/5/2016[5]	36 inch hollow concrete	Colman Dock	43	84	83	109	108	N/A
2/8/2016[5]	18 inch octagonal concrete	Colman Dock	36	92	89	111	108	N/A
11/17/2014[6]	30 inch	SR 520 WABN	26	103	97	113	107	N/A

Note: All piles are steel unless otherwise noted.
N/A = no data
[1] (WSDOT, 2006)
[2] (WSDOT, 2007)
[3] (Illingworth & Rodkin, 2010)
[4] (WSDOT, 2016a)
[5] (WSDOT, 2016b)
[6] (WSDOT, 2015)

Un-weighted Impact Driving

Date	Pile Size (inches)	Location	Distance (ft)	Measured Leq (dB)	Leq at 50 ft. (dB)	Measured Lmax (dB)	Lmax at 50 ft. (dB)	Hammer Size/Type
11/10/2010[1]	72	SR 529 Ebey Slough Bridge Replacement	33	106	102	109	105	APE D-100-17
12/7/2015[2]	30	Vashon Ferry Terminal	66	96	97	112	113	N/A
12/7/2015[2]	30, double walled	Vashon Ferry Terminal	66	100	101	111	113	N/A
2/2/2016[3]	36	Colman Dock	75	97	101	112	115	N/A
2/3/2016[3]	36, hollow concrete	Colman Dock	33	102	98	119	115	N/A
2/8/2016[3]	18, octagonal concrete	Colman Dock	36	97	94	111	108	N/A

Note: All piles are steel unless otherwise noted.
N/A = no data
[1] (WSDOT, 2011)
[2] (WSDOT, 2016a)
[3] (WSDOT, 2016b)

A-Weighted Vibratory Driving

Date	Pile Size (inches)	Location	Distance (ft)	Measured Leq (dBA)	Leq at 50 ft. (dBA)	Measured Lmax (dBA)	Lmax at 50 ft. (dBA)	Hammer Size/Type
11/1/2009[1]	30	Vashon Ferry Terminal	36	81	80	97	96	APE Vibratory
10/26/2010[2]	24	SR 520 WABN	410	76	94	82	100	N/A

Note: All piles are steel unless otherwise noted.
[1] (WSDOT, 2010)
[2] (Illingworth & Rodkin, 2010)

Un-weighted Vibratory Driving

Date	Pile Size (inches)	Location	Distance (ft)	Measured Leq (dB)	Leq at 50 ft. (dB)	Measured Lmax (dB)	Lmax at 50 ft. (dB)	Hammer Size/Type
12/13/2010[1]	18	Wahkiakum County Ferry Terminal	39	89	88	95	94	APE Vibratory
1/9/2010[2]	30	Keystone Ferry Terminal	40	97	97	104	103	APE Vibratory

Note: All piles are steel unless otherwise noted.
[1] (WSDOT, 2010b)
[2] (WSDOT, 2010c)

References

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