Hydroacoustic Biological Assessment Guidance
(Assessment of Underwater Sound Pressure)

Introduction

Projects that involve pile driving in or near water can contribute to increased underwater sound pressure in marine and freshwater environments. Injury and fish mortality have resulted from driving large in-water piles on projects in San Francisco Bay, Puget Sound, and British Columbia. An evaluation of anticipated hydroacoustic impacts is required for permits and agreements to ensure compliance with state and federal environmental laws and regulations. This guidance focuses on the biological analysis required to evaluate the potential effects on fish from underwater sound pressure generated by pile driving.

Underwater sound pressure is an issue of concern, particularly for listed fish species under the authority of the California Department of Fish and Wildlife, NOAA Fisheries, and the U.S. Fish and Wildlife Service (Services), and for projects within jurisdiction of the California Coastal Commission (CCC).

The purpose of this guidance is to provide California Department of Transportation biologists and its consultants with an understanding of the required analysis and step-by-step guidance for using the available tools and data to assess potential impacts to fish and their habitat from underwater sound pressure generated during pile driving or other percussive actions (e.g., blasting, use of a hoe ram for demolition, etc.). This guidance can be used to assist in the preparation of both California (state) and federal Endangered Species Acts (California Endangered Species Act [CESA] and federal endangered Species Act [FESA]) biological assessments (BA), Essential Fish Habitat (EFH Assessments), Coastal Development Permits (CDP), and other environmental permitting, or documentation, for projects that have the potential to increase underwater sound pressure.

Information on the fundamentals of hydroacoustics, foundations engineering, attenuation methods, best management practices, impacts to fish, tools for biologists, and the compendium of project data is available to Department biologists, engineers, and project development teams in the following documents:

- Caltrans "Technical Guidance for Assessment and Mitigation of Hydroacoustic Effects of Pile Driving on Fish", hereto referred to as the 'guidance manual'

Project-specific foundations design and construction information is needed early in the project delivery process, for FESA consultation, to successfully meet the Project Approval and Environmental Document (PA&ED) milestone. Federal law requires that the FESA BA is completed with the Federal Environmental Document. Depending on the complexity of the project, FESA consultation can take 6 or more months to complete. Early Project Delivery Team coordination is needed, with engineering geologists and structures foundations designers, to determine the project site substrate, which dictates the recommended foundation types and informs estimated strike counts. If driven piles are recommended as the feasible foundation type in the Preliminary Foundations Report (PFR), Structures and Geotech PDT members will provide an estimated strike count based on site-specific substrate, using a one-dimensional Wave Equation Analysis program (GRE WEAP), that simulates the pile type and depth to refusal (final elevation).

The Project Checklist is included, starting on page 9 of this guidance, which details project information needed for preparation of the hydroacoustic biological analysis. The checklist allows the project biologist to evaluate effects of anticipated underwater sound pressure levels on fish and other in-water species. Certain items may not be applicable, and/or additional items may be requested, during consultation with state and federal resource agencies.

During project construction, underwater sound pressure levels are monitored to verify that they are within the predicted values calculated for the species impact analysis, and to determine the effectiveness of underwater sound pressure attenuation devices. Underwater sound pressure levels are measured with a hydrophone, or underwater microphone, which is a transducer that converts the sound pressure to an electrical signal. To standardize data collection to facilitate comparison between sites and projects, hydroacoustic data is collected by placing the hydrophone 10 meters from the source (the pile being driven). The hydrophone sensor is placed in the water column in at least 1 meter of water depth. Caltrans has a monitoring plan that can be accessed at the link below. Monitoring plans should specify the minimum water column depth and the depth of the hydrophone.

- Caltrans Underwater Noise Monitoring Template is located on the Caltrans Hydroacoustics web page

Underwater sound pressure levels are not weighted (expressed as decibels [dB]) and thus measure all frequencies unmodified within the range of interest, which may extend below and above the audible range of many organisms.

The dual metric criteria, per the 2008 Interim Criteria agreement, are the instantaneous peak sound pressure level (SPL) and the accumulative sound exposure level (cSEL). The peak is the single-strike maximum anticipated sound pressure level. The cSEL is a measure of 90% of the total energy of the peak strike, which accumulates throughout the driving event. It equates to the total sound pressure energy that a fish would be exposed to if it remained within the pile driving action area throughout the entire event. These criteria are used to determine the potential for physical injury to fishes. NOAA Fisheries also uses the RMS (dB_{RMS}) to describe disturbance-related effects (i.e., harassment, behavioral impacts) to fish from exposure to underwater sound pressure.

- Peak Sound Pressure Level (SPL)
    - **206 dB** for all sizes of fish
- Accumulated Sound Elevation Level (cSEL)
    - **187 dB** - fish two grams or greater
    - **183 dB** - fish less than two grams
- **150 dB** – Effective Quiet (RMS) assumed background levels

Although there are many sources of underwater sound pressure in the aquatic environment (e.g., boat noise, offshore oil/wind, dock building, revetment projects, etc.), the most common sources of underwater sound pressure associated with Caltrans' construction activities is impulsive sound pressure generated from pile driving. Underwater sound pressure from pile driving is generated using different types and sizes of piles and hammers, and in varied substrate types. Each project-specific configuration can produce differing underwater sound pressure levels.

Underwater sound pressure generated by vibratory hammers is considered a continuous sound. The wave form has a slower rise time, and the energy produced is distributed over the time it takes to drive the pile(s), during daily driving events. Vibratory driving underwater sound pressure levels are lower than impact hammer driving underwater sound pressure levels. There is no current vibratory pile driving threshold for fish because vibratory driving is an avoidance/minimization measure as compared to impact driving. Wave form characteristics from vibratory driving are far less impactive to aquatic organisms.

For proposed projects in which the pile type, size, and depth to final elevation are estimated to exceed the Peak and SEL thresholds, attenuation methods are required as reasonable, feasible actions that minimize the radius of daily and seasonal underwater sound pressure generated from the project action. An explanation of varied design and attenuation avoidance and minimization measures can be found in Chapter 4 of the guidance manual. When considering attenuation:

- The more pile surface exposed under the water, the more underwater sound pressure will radiate directly into the aquatic environment.

- Bubble attenuation devices typically work well within deeper water habitats. Confined bubble devices should be used if any velocity is anticipated.

- Shallower water (e.g., water 2 feet or less) does not propagate underwater sound pressure effectively. However, sound pressure levels may be high because of refraction—propagation of underwater sound pressure waves through the substrate, radiated back into the water.

Construction Equipment and Methods

Sheet piles for coffer dams typically use vibratory drivers, which vibrate the sheet pile into the sediment by use of an oscillating head that liquifies the substrate, thus allowing the action to slowly sink the sheet pile into the sediment. In some cases, permanent and temporary foundation piles can be vibrated to "start" the pile, but it is not feasible to drive load bearing piles to final depth using vibratory methods. Vibratory methods for steel shell or h-beam piles using liquification achieve only a shallow depth (~10 meters or less), but can be used as a feasible method to minimize the total number of pile strikes needed to drive a permanent load-bearing pile to refusal (final elevation). To drive a load bearing pile to final depth, it must be struck repeatedly with a hammer, which is called "proofing a pile." The amount of strikes required to achieve final depth varies depending on site-specific characteristics.

When using vibratory methods to start load bearing piles, vibratory peak sound pressure levels for very large piles can exceed 206 dB at 10 meters from the pile; however, the rise time is relatively slow. Although physical injury has not been observed from vibratory underwater sound pressure levels on fishes or other aquatic organisms, mechanized impacts can occur if vibratory methods are in, or near, spawning gravels in which vibration can shake gravels and smother eggs.

Transmission Loss

Transmission loss (TL) for underwater sound pressure is the accumulated decrease in acoustic intensity as the pressure wave propagates outwards from the action. The intensity of the underwater sound pressure is reduced with increasing distance due to spreading. Spreading for in-water pile driving is usually considered using the practical spreading loss model. For more in-depth consideration of transmission loss in water or on land, refer to Chapter 2, Fundamentals of Hydroacoustics, and Chapter 4, Framework and Process, in the Caltrans hydroacoustic guidance manual.

The standard TL, used by experts and included as a default in the NMFS calculator tool, is 4.5 dB per doubling of distance. However, many construction projects produce underwater sound pressure in shallow water, and reflections from the sediment, or water surface, can considerably reduce spreading. Because of the complexity of these reflections, it is difficult to define TL. Because underwater sound pressure energy is not perfectly contained by reflection and refraction, most experts agree that the true spreading is often somewhere between 3 and 6 dB per doubling of distance. The standard of 4.5 dB per doubling of distance assumes that underwater sound pressure decreases at a rate between the spherical (6 dB) and cylindrical (3 dB) models.

In 2008, the Services created an XL spreadsheet, "NMFS calculator," a basic tool that estimates the distance to the 2008 Interim dual metric criteria threshold levels. Because the calculator is not ADA compliant, it is only available on the internal Caltrans hydroacoustic website (intranet), or provided upon request.

Consideration of Underwater Sound Pressure Reduction

The method of determining how underwater sound pressure reduces by attenuation, or transmission loss, as it moves away from the source can be difficult to determine, requiring site specific considerations. The method depends on sediment types, bottom topography, structures in the water, bottom slope, temperature gradients, currents, tidal flux, and wave height. Underwater sound pressure propagation in river systems can be limited by the sinuosity of a system. For example, underwater sound pressure is unlikely to propagate as readily in a river bend.

Listed Species Impacts from Underwater Sound Pressure

Underwater sound pressure generated by impact pile driving has the potential to affect listed fish in several ways. The range of effects potentially includes alteration of behavior to physical injury or mortality, depending on the intensity and characteristics of the underwater sound pressure, the distance and location of fish in the water column relative to the sound source, the size and mass, and the anatomical characteristics (Yelverton et al. 1975—cited in Hastings and Popper 2005). For more information on the effects of underwater sound, refer to Caltrans' "Technical Guidance for Assessment and Mitigation of Hydroacoustic Effects of Pile Driving on Fish."

Beginning in 2002, various experts and studies had recommended a range of injury and behavioral effects thresholds for salmon. Based on consideration of expert recommendations, in June of 2008, Caltrans, the Federal Highways Administration, Washington DOT, Oregon DOT, Regions 1 and 8 of the U. S. Fish and Wildlife Service (USFWS), and NOAA Fisheries reached agreement on interim fish sound exposure thresholds.

The 2008 Interim thresholds for onset of injury from impact pile driving for fish are:

- Peak Sound Pressure Level (SPL) – onset of injury to fishes
  - **206 dB** for all sizes of fish
- Accumulated Sound Elevation Level (cSEL)- accumulated, daily dose onset of injury for 2 class sizes of fish
  - **187 dB** - fish two grams or greater
  - **183 dB** - fish less than two grams

For the analysis, the number of strikes is estimated by Geotechnical and Structures engineering, based on the number of strikes estimated to occur in an accumulation period, which is defined as the daily driving action, with a break of 12 or more hours before the next driving event. The clock resets only after a break of 12 or more hours. The break allows fish to move out of the affected areas and to recover from sub-injurious accumulation of underwater sound pressure energy.

If the cumulative SEL threshold is exceeded, physical injury to fish is unlikely (no research or projects with data to support any physical injuries associated with the cSEL threshold currently exist). However, the 2008 interim criteria remain until agencies work together to develop needed updates to the current interim criteria. The project specifics, site-specific factors, such as local habitat conditions, and species-specific factors influence whether physical injury occurs from exceedances of the Peak metric. A key consideration is whether the fish being analyzed are stationary, or are migrating through an area. The Services assume that single strike SELs below 150 dB RMS do not accumulate to cause injury ("effective quiet") and thus set a limit on the maximum distance from a pile that a fish could incur potential injuries. However, the best available science demonstrates no physical injuries associated with the accumulated sound elevation level (cSEL). The dual metric criteria, particularly the cSEL, continues to be overly conservative. Without expert consideration, particularly when negotiating CESA consultation, mitigation for assumed injuries within this isopleth should use the best available science and data and should not indicate elevated ratios of mitigation for assumed physical injury within the cSEL area.

Although not in the interim criteria, the Services arbitrarily set a 150 dBRMS as a guideline for underwater sound pressure levels that may result in behavioral (i.e., sub-injury) effects to fish. The 150 dBRMS guideline for potential behavioral effects may be considered in some consultations depending on location and the time of year the work is occurring. Research and projects conducted since 2008 have not detected a significant difference in resultant impacts to fish between the cSEL and RMS defined areas. Currently, the Services have concluded that sound pressure levels greater than 150 dBRMS are estimated to cause temporary behavioral changes, such as elicitation of a startle response, or feeding disruption. Depending on site-specific conditions, project timing, project duration, species life history, relative population estimates, and other factors, exposure to these levels may cause behavioral changes that result in "take." Those levels are not expected to cause direct physical injury, but may indirectly affect the individual (such as impairing predator detection).

The Services allow incidental take (i.e., take that results from, but is not the purpose of, carrying out an otherwise lawful activity—in this case, causing harm to a listed species) through the ESA Section 7 consultation process. However, prior to being issued an incidental take statement, the project must minimize impacts to the extent that is feasible. Minimization measures for pile driving projects may include designing the structure to span the channel so that piles are land-based during the low flow construction season, selecting project timing to avoid in-water work during key life history stages, such as fish spawning, using a vibratory driver to start the pile, and incorporating sound attenuation methods, such as a bubble curtain, or other devices, when impact driving is anticipated to exceed the peak 206 dB. Chapter 3 of the guidance manual provides additional information in consideration of applying fish thresholds.

The threshold levels described in the above sections can be used to define the zone of potential harm and harassment and injury for ESA-listed fish. For example, the zone of injury would occur in the area where project-related underwater sound pressure levels have not yet attenuated below the injury threshold levels. These are the distances estimated using the NMFS calculator.

Impact Assessment for Underwater Sound Pressure

Design considerations, best management practices (BMPs), avoidance and minimization measures, and performance standards form the basis of the analysis. The analyses occurs during PA&ED and, in consideration of the FESA consultation, and requires a detailed project description to include pile types and sizes, depth to elevation, modeled strike-count estimates, locations of permanent and temporary piles, and access to in-water and adjacent land-based action areas (e.g., temporary bridges, trestle, barges, temporary fill, etc.) as well as timing and attenuation, or isolation, methods (e.g., coffer dams, bubble curtains, water bladders, etc.).

Typically, this information is collected by the biologist in coordination with the project development team (PDT), to include Geotechnical services with input from Structures foundations engineering. The information gathered is needed to estimate the underwater sound pressure that is likely to occur during project actions. The required project metrics include the number of piles, number of strikes per pile, estimated number of total strikes per day (based on the construction schedule for planned, daily pile driving productivity), and phasing of pile driving activities. These metrics allow for an estimate of peak and accumulated daily underwater sound pressure for defined project activities and daily construction progress.

Information on the consultation history typically refers to any coordination with CDFW or the Services, regarding project-related potential effects on state, or federal, listed, species and their habitats. It is particularly important to discuss any modifications to the project design, or timing, in response to federal, state, or local agency requirements or recommendations.

A description of special-status fish species is required to determine species and life history stages that may be exposed to underwater sound pressure during pile driving. Project species lists are generated by the Services and are based on current and historic occupied habitat areas. The Standard Environmental Reference (SER) has additional information on methods to generate a species list and timing requirement for updating species lists for project milestones.

- Caltrans "SER, Volume 3: Biological Resources, Chapter 4, Section 4-2.2" is located on the Caltrans Standard Environmental Reference Volume 3 website

A description of area habitat types and life history phases is required to assess species potentially present in the action area and the number of fishes potentially affected by underwater sound pressure. Many of the listed species addressed through consultation are anadromous. Anadromous fish spawn and rear juveniles in freshwater, the juvenile fish migrate to the ocean to rear to adults, and the adults then return to their natal freshwater to spawn. The location of the project in the watershed and the timing of the project in relation to life cycle are important factors to consider in determining potential fish species present, the life stage of those fish species, and numbers of fish that could be exposed to pile driving underwater sound pressure. Resource agency partners should be contacted to discuss and help determine the in-water work windows when pile driving should occur. The agencies have established in-water timing windows to minimize effects of construction activities on juveniles of anadromous fishes (particularly salmon and steelhead) and other listed species.

In some locations, sensitive fish species are present year-round. For example, rearing Coho salmon and Steelhead can be present throughout the year, particularly in coastal streams. Green sturgeon is considered present year-round in the Bay Delta and Sacramento River. Species of Eulachon, Sacramento splittail, Tidewater goby, and Delta and Longfin smelts are present year-round.

Note: Over air decibel level work-window restrictions may also apply if listed bird species (e.g., northern spotted owl, marbled murrelet, peregrine falcon, etc.) have the potential to nest in, or near, pile driving action.

Project Information Checklist

This checklist indicates project information needed for preparation of the hydroacoustic biological analysis. This information will assist the project biologist in evaluating effects of anticipated actions that produce underwater sound pressure levels, as well as impacts to fish and other in-water species. Certain items may not be applicable, and/or additional items may be requested, during consultation with state and federal resource agencies.

Project Information Description	Needed	Completed
Project Description: Describe the location, purpose, need, and basic design and construction methods.		
Environmental Setting: Describe the drainage, indicate the width, depth, approximate flow, whether tidally influenced, fresh, salt, or estuarine conditions, and the habitat types present.		
Special-Status Species: Identify special-status species that have the potential to occur in the project action area. Review the Standard Environmental Reference for guidance on acquiring state and federal-listed species lists with the potential to occur in the project action area. Document any designated critical habitat within the project action area.		
Essential Fish Habitat (EFH): Identify EFH within the project action area. The EFH analysis is included within the Biological Assessment. The Pacific Salmon EFH in California includes only Chinook and Coho salmon habitats.		
Agency Consultation: Provide information regarding consultations (e.g., meetings, phone discussion, decisions, prior written documentation), and include any changes made to the project description.		

Pile and Driving Activities Description	Needed	Completed
Type(s) and number of piles: Specify the number of permanent and temporary piles; include the size and locations of piles (e.g., 24-inch steel shell piles, in approximately 2 meters of water).		
Location of piles in the channel: Provide plans that include the water depth and channel width in design plan view. Illustrate the approximate locations of temporary and permanent piles. Indicate the location of piles not driven in the water to ordinary high water.		
Type(s) of Pile Driver(s) to be used: Identify whether impact hammer, vibratory, or other type of hammer would be used.		
Project Phasing for Pile Driving: Indicate the duration of the project, (e.g., work proposed during which years and/or work windows).		
Number of Pile Strikes per Day: Estimate the number of strikes per pile to final elevation, based on the pile type and project substrate (engineers estimate).		
Number of piles Driven Per Day and Total Pile Driving Days: Provide an estimate of the number of piles anticipated to be driven in a day and how many hours of pile driving expected per working day (a 12-hour rest period is required between driving events).		

Attenuation Description	Needed	Completed
Cofferdams: Are cofferdams proposed for foundations construction? If yes, will the cofferdams be excavated and dewatered for footing construction? If proposed, provide information on size, location, placement methods, and when they will be installed and removed.		
Sound Pressure Attenuation: For pile driving proposed within the wet channel with an estimated peak elevation of 206 dB or greater (i.e., 24-inch CISS piles or larger), identify the attenuation proposed for use (e.g., bubble curtain, isolation casing, dewatered cofferdam), and indicate which piles will be used for attenuation. Estimate the decrease in sound pressure due to the attenuation device.		
Methods of Evaluation: Describe the methods used to evaluate the potential effects on fish of pile driving noise (e.g., NMFS calculator, etc.).		

Results – Reporting the Outcome of the Analysis	Needed	Completed
Project Action Area: Define the project action area for pile driving. The distance at which the generated underwater sound pressure attenuates to the background level is considered the project action area for pile driving sound pressure. The injury threshold is generally a much smaller area.		
Acoustic Impact Area: Use the calculator tool and compendium data to estimate transmission loss of underwater sound pressure for the dual metric injury threshold (Peak and cSEL), as well as the distance to the estimated default for sub-injurious impacts (currently 150 dB RMS). Include, in the appendix of the application, the XL calculator tool for each pile type/size.		
Impact Assessment: Estimate the number of individual listed species and/or area of critical or species habitat potentially affected by project generated underwater sound pressure.		

Avoidance, Minimization, and Mitigation	Needed	Completed
Project Timing: List work windows for aquatic, or other species.		
Best Management Practices: Include designs that purposely span the channel, which increase project cost but minimize in-channel work needed. Include any proposed temporary trestles, barges, or other access that minimizes impacts to avoid fill within the channel. Include water bladders or coffer dams that isolate work areas for water quality.		
Attenuation: Include any attenuation devices that minimize the isopleth areas of peak and accumulative underwater sound pressure (e.g., bubble curtains, coffer dams, isolation casing, etc.)		
Mitigation for take of Listed Species: Identify the potential mitigation for take of state-listed species. Under CESA, the State requires mitigation for take. The mitigation must offset the loss of individuals due to the project. Use the best available science, surveys, and population estimate models.		
Performance Measures: Identify performance measures and proposed underwater noise monitoring to verify project underwater sound pressure estimates during construction actions. *Note:* Projects often propose to monitor a cross section of piles types/sizes, and then discontinue if estimates are at, or below, the estimated levels. Large, complicated projects may need to propose continuous monitoring.		

Summary of Typical Strike Data

To inform the Biological Assessment, Structures and Geotech PDT members will provide an estimated strike count based on site-specific substrate, using GRE WEAP, which simulates the project locations for a site-specific strike count estimate. Appendix A of the guidance manual includes a compendium of project data, which should be used to find a suitable comparison project with commensurate pile types and sizes. Some considerations for analysis:

- If the project location is in a river, bay or estuary, find a comparable project, in a similar setting, that used the exact same pile type and size.
- If data for a specific pile size, or type, is not available in the compendium, contact headquarters subject matter experts for assistance in selecting an appropriate comparison project.
- If data for an appropriate pile size or type is unavailable, use a pile that is larger. Do not use a comparison pile that is smaller, or not the same type.
- Chapter 4, Framework, of the guidance manual, includes examples of typical pile types, strike counts for specific projects, and an example summary of project information and estimated impact areas.

Attenuation to Reduce Underwater Sound Pressure

Various methods and devices have been used to reduce underwater sound pressure from in-water pile driving. These methods either reduce the transmission of sound through the water, or reduce sound pressure generated by the pile.

These methods are outlined in Chapter 4.4, Avoidance and Minimization Measures, Best Management Practices and Performance Standards. Examples of effective attenuation devices commonly deployed on projects by the Department include confined and unconfined air bubble curtains, double-walled isolation casings, and cofferdams. Other avoidance and minimization methods include starting the pile with a vibratory driver, or designing the bridge to span the channel, thus driving piles on land, near water.

The use of a sound attenuation device can reduce in-water sound pressure levels. However, because of the large variability in the effectiveness of bubble curtains, the expected level of attenuation from these, or any other sound attenuation device, should be considered by the PDT and discussed with the Services prior to submitting the BA.

Using the NMFS Calculator Tool

Once the comparison project from the compendium has been selected, use the NMFS calculator tool to input project estimate data:

- Input comparison project pile type and size compendium data into the green boxes for peak, single-strike SEL, and RMS data.
- Use the strike count provided by DES Structures foundations or geotechnical engineers, which used GRE WEAP software to simulate the pile types and depth to final elevation for the project site substrate.
- If multiple pile types, or varied attenuation devices, are proposed, use the NMFS calculator several times to capture potential scenarios and to assess an accurate range of estimated attenuation for each pile type and size.
- Appropriately applied attenuation, or land-based pile driving adjacent to water, will not require a modified F value for the NMFS calculator to adjust for transmission loss. Overestimating TL can cause delays during construction. If you think the F value may need to be modified, contact subject matter experts for assistance. Unless otherwise specified, a standard default value of 15 should be used, which is the assumed value.
- The cSEL threshold for fish size is determined by the species and life stage expected to occur in the project hydroacoustic action area during construction. The SEL will be 183 dB for fish that are less than 2 grams and 187 dB for fish greater than 2 grams. *Note:* Fish less than 2 grams are typically found in marine and estuarine areas.
- The NMFS calculator will estimate the distance from the pile driving action to the thresholds for injury and sub-injury.
- These distances represent estimates of areas of injurious and sub-injurious impacts (>206 dB, peak and >183/187 dB cSEL) as well as the hydroacoustic project action area (150 dB RMS).
- If fish distribution data is available, use it to estimate the number of individuals likely to be present in the affected area during pile driving.

Additional analysis information is available in the Caltrans guidance manual. Below is an example of the completed analysis tool;

Project Title	**Example River Bridge - Permanent Foundation Piles**			
Pile information (size, type, number, pile strikes, etc.)	**24- inch Steel Shell Pipe Piles, Diesel Impact (Delmag D46-32), Excavated and dewatered coffer dam used for permanent foundation, in-water pile driving. Estimates strikes per pile = 1,250. The project proposes to drive 3 piles per day = 3,750.**			
Fill in green cells: Estimated sound levels and distances at which they were measured, estimated number of pile strikes per day, and transmission loss constant.				
	Acoustic Metric			
	Peak	SEL	RMS	Effective Quiet
Measured single strike level (dB)	**203**	**174**	**185**	**150**
Distance (m)	**10**	**10**	**10**	
Estimated number of strikes	**3750**			
Cumulative SEL at measured distance				
209.74				
	Distance (m) to threshold			
	Onset of Physical Injury			Behavior
	Peak	Cumulative SEL dB**		RMS
	dB	Fish ≥ 2 g	Fish < 2 g	dB
Transmission loss constant (15 if unknown)	206	187	183	150
15	**6**	**328**	**398**	**2154**
** This calculation assumes that single strike SELs < 150 dB do not accumulate to cause injury (Effective Quiet)				
Notes (source for estimates, etc.)				
Amorco Wharf project in Martinez, CA was selected for comparison data due to proximity of the proposed project with likely similar substrate, as well as the same pile type and size. Piles at Amorco were attenuated by use of an air bubble curtain, while the permanent footing array for the 24" CISS foundation piles will be isolated from the wet channel and contained within an excavated and dewatered coffer dam. Due to these circumstances, similar levels of attenuation are anticipated.				

Caltrans "Technical Guidance for Assessment and Mitigation of Hydroacoustic Effects of Pile Driving on Fish"

Hastings, M.C. and A.N. Popper. 2005. Effects of Sound on Fish. White Paper. January 2005.