RESEARCH PROPOSAL
SUBMITTED TO THE
U.S. ARMY CORPS OF ENGINEERS
Northwestern Division

I. Basic Information

A. Title

The Dalles Dam Fish Ladder Auxiliary Water System Vibration Monitoring

B. Project Leaders

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C. Corps Technical Point of Contact

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D. Anticipated Duration

September 28, 2017 to September 31, 2018

E. Date of Submission

September 5, 2017

II. Project Description

A. Project Goal(s)

This scope of work was prepared by the Pacific Northwest National Laboratory at the request of the U.S. Army Corps of Engineers District, Portland, Oregon (Portland District). The goal of this project is to monitor low frequency sound and vibration levels at the fish ladder including establishing a non-construction baseline and monitoring nighttime construction.

B. Background

The U.S. Army Corps of Engineers is planning to modify the Fish Ladder Auxiliary Water System at The Dalles Dam in October 2017. To mitigate potential delay impacts to migrating salmonids associated with the planned construction work, vibration of the East Fish Ladder support columns in the vicinity of the excavation area will be monitored and recorded during construction activities.

The behavior of salmon in response to underwater sounds is still largely unknown. Salmon have relatively poor hearing with a sharp cut-off frequency of 380 Hz. Typically, salmon are sensitive to particle motion (bulk motion of water resulting from pressure wave propagation) rather than sound pressure (Hawkins and Johnstone 1978; Knudsen et al. 1992; Redford et al. 2012), so it is necessary to measure the particle motion in addition to sound pressure.

C. Methods

Task 1: Preparation, data collection, and daily report

We plan to deploy two identical measurement systems at two deployment sites (Figure 1). Each system will consist of a data acquisition system and sensors. To measure the particle motion in terms of acceleration in three (x-, y-, and z-) directions, three high-sensitivity (approximately 1000 mV/g) accelerometers (PCB Piezotronics model 393A03) will be rigidly mounted in perpendicular directions (Figure 2). The three accelerometer cables will be bundled and routed to a weatherproof enclosure. A solar power system (i.e., solar panel, charge controller, and at least one 12V battery) will be located near each deployment site, with the solar panel mounted on a standalone structure that will allow the panel to be aimed toward the southern sky. Ideally we would like to place the enclosure in a location that will offer some shade. The PCB Piezotronics model 393A03 accelerometers we proposed to use are designed to measure ultra-low amplitude, low frequency vibrations. They have a frequency range of 0.5 Hz to 2 kHz and a broadband resolution of 0.0001 m/s^2. All accelerometers will be calibrated in the laboratory prior to field deployment.

Monitoring shall commence at least 7 days prior to work starting and run continuously for those 7 days to develop baseline noise and vibration levels. Processed baseline data and analysis shall be submitted no later than the day construction activities begin. Operational data will be provided by the USACE so that vibration monitoring data can be related to specific equipment and activities. Processed data will be provided to the USACE by 10 AM the following work day for analysis.

Figure 1 Proposed sensor deployment sites at The Dalles Dam Fish ladder.

Figure 2: Three single-axis accelerometers will be attached to the wall.

Task 2. Data analysis and reporting

The accelerometers will be deployed in a right handed coordinate system where channels 1, 2, and 3 corresponded to X, Y, and Z. Data will be saved as waveform audio files with ±1 V amplitudes. The actual measuring range of the data acquisition system that will be used is -2.5 V to 2.5 V (i.e., scaled to ±1 V before saving), raw sound pressure data and acceleration data will be multiplied by 2.5, and then converted to physical units (m/s^2) according to the calibration sheet, similar to the data process method described by Ren et al. (2011). Bad data files will be detected and excluded from data analysis.

Then, the magnitude of acceleration was calculated with

$$a = \sqrt{{a_x}^2 + {a_y}^2 + {a_z}^2}.$$

Given the measurement range of the accelerometers and that the sampling frequency will be 2000 Hz, the acceleration magnitude data will capture frequency components in the 0.5 to 1000 Hz band. To evaluate the acceleration in the infrasound frequency range, the acceleration magnitude will be filtered by a bandpass filter after discussing the suitable frequency range with USACE. Both the unfiltered and the bandpass filtered acceleration will be processed in the following metrics:

- **Acceleration peak**: the maximum absolute amplitude value in the signal during a specified time interval, with the unit of m/s^2;
- **Acceleration RMS**: the square root of the average square acceleration magnitude of the signal over a specific time interval, with the unit of m/s^2.

The acceleration data will be recorded in one-minute-long audio files. The sound acceleration metrics will be calculated within every second, and then in every minute and every hour respectively. The results calculated from every second or minute show the instantaneous variation of each of the metrics, while the hourly measurements show the long term variations.

Salmonids are believed to be sensitive to particle motion rather than sound pressure. Knudsen et al. (1992) reported that a particle acceleration of 0.01 m/s^2 (80 dB relative to 1 $\mu m/s^2$) at 3 m deterred downstream migrating Atlantic salmon smolts in a river. Percentage rate over threshold will be calculated for acceleration RMS and peak values in every minute to evaluate levels of accelerations at study sites.

D. Schedule

The project is scheduled to start on September 28, 2017. A final work schedule will be developed collaboratively during the initial pre-work meeting, after the contract has been awarded. Preparatory work will begin on the date that the contract is awarded.

A draft letter report will be prepared and delivered no later than June 30, 2018. A final report incorporating changes to the draft report resulting USACE review will be submitted no later than September 30, 2018. Modifications of these delivery schedules may be implemented after discussions with the USACE technical points of contact.

III. List of Key Personnel and Project Duties

Name (Affiliation)	Duties
Z. Daniel Deng, Ph.D. (PNNL)	Principal Investigator
Jayson Martinez (PNNL)	Field study coordinator
Scott Titzler (PNNL)	Sensor deployment
Xiaqin Zang, Ph.D. (PNNL)	Data analysis
Jun Lu, Ph.D. (PNNL)	Data acquisition system design

IV. Literature Cited

Hawkins, A.D., and A.D.F. Johnstone, 1978. The hearing of the Atlantic Salmon, Salmo salar. Journal of Fish Biology 13:655-673.

Knudsen F.R., P.S. Enger, and O. Sand, 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, Salmo salar L. Journal of Fish Biology 40:523-534.

Ren H., M.B. Halvorsen, Z.D. Deng, and T.J. Carlson, 2012. An aquatic acoustic metrics interface utility for underwater sound monitoring and analysis. Sensors 12(6):7438-7450.

Redford C.A., J.C. Montgomery, P. Caiger, and D.M. Higgs. 2012. Pressure and particle motion detection thresholds in fish: a re-examination of salient auditory cues in teleosts. Journal of Experimental Biology 215:34299-3435.

V. Budget

The budget will be submitted under separate cover.