Report

Vibration Management Plan

Ashland/NSP Lakefront Site

Project I.D.: 12X001

NSPW
Eau Claire, Wisconsin

April 2014

Foth | Envirocon
Joint Venture

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Joint Venture

101 International Drive, P.O. Box 16655
Missoula, MT 59808

April 10, 2014

Mr. Richard M. Halet
Project Manager
Xcel Energy, Inc., on behalf of NSPW
414 Nicollet Mall, MP 7A
Minneapolis MN 55401

Dear Mr. Halet:

RE: *Vibration Management Plan*
Ashland/NSP Lakefront Site

On behalf of Foth Infrastructure & Environment/Envirocon Joint Venture, the *Vibration Management Plan (VMP)* for the Ashland/NSP Lakefront Site is enclosed.

Revisions were made to this *VMP* based on several sets of comments received from the U.S. Environmental Protection Agency (USEPA). A revised *VMP* has also been posted to the FE JV SharePoint site.

If you have any questions concerning this report, please contact either of the undersigned at (920) 497-2500.

Sincerely,

Foth Infrastructure & Environment/Envirocon Joint Venture

Steve J. Laszewski, Ph.D.
Management Committee Member

Michael S. Raimonde
Project Manager

Vibration Management Plan

Distribution

No. of Copies	Sent To
1	Richard C. Karl Director, Superfund Division U.S. Environmental Protection Agency 77 W. Jackson Blvd. (SR-6J) Chicago IL 60604-3590
1	Scott Hansen Remedial Project Manager U.S. Environmental Protection Agency 77 W. Jackson Blvd. (SR-6J) Chicago IL 60604-3590
1	Jamie Dunn Project Manager Wisconsin Dept. of Natural Resources 810 W. Maple St. Spooner WI 54801
1	Michael S. Raimonde Foth Infrastructure & Environment, LLC Lincoln Center 2514 S. 102nd St., Suite 278 Milwaukee WI 53227
1	Todd Fryzek RD QA Manager Foth Infrastructure & Environment, LLC Eagle Point II 8550 Hudson Blvd N, Suite 105 Lake Elmo MN 55042

No. of Copies	Sent To
1	Jerry Winslow Project Coordinator Xcel Energy, Inc., on behalf of NSPW 414 Nicollet Mall, MP 4C Minneapolis MN 55401
1	Richard M. Halet Project Manager Xcel Energy, Inc., on behalf of NSPW 414 Nicollet Mall, MP 7A Minneapolis MN 55401
1	Steve Laszewski Management Committee Member Foth Infrastructure & Environment/Envirocon Joint Venture 2121 Innovation Ct. Suite 300 De Pere WI 54115
1	Alan Buell Deputy Project Manager and RA Construction Manager Envirocon, Inc. 651 Corporate Circle, Suite 114 Golden CO 80401
	Master Project Files Foth Infrastructure & Environment/Envirocon Joint Venture

Vibration Management Plan

Project ID: 12X001

Prepared for
NSPW

Eau Claire, Wisconsin

Prepared by
Foth Infrastructure & Environment/
Envirocon Joint Venture

April 2014

101 International Drive, P.O. Box 16655 • Missoula, MT 59808

Vibration Management Plan

Contents

Tables

Figures

Appendices

List of Abbreviations, Acronyms, and Symbols

FE JV	Foth Infrastructure & Environment/Envirocon Joint Venture
MTTD	medium temperature thermal desorption
NSP	Northern States Power Company
NSPW	Northern States Power Company, a Wisconsin Corporation
QA	quality assurance
RA	remedial action
RA HASP	*Remedial Action Health and Safety Plan*
RD	remedial design
Site	Ashland/Northern States Power Lakefront Site
USEPA	U.S. Environmental Protection Agency
Vibra-Tech	Vibra-Tech Engineers
VMP	*Vibration Management Plan*
Wis. Admin. Code	Wisconsin Administrative Code

1 Introduction

1.1 Overview and Purpose

This *Vibration Management Plan* (*VMP*) is being prepared on behalf of Northern States Power Company, a Wisconsin Corporation (NSP/NSPW) by Foth Infrastructure & Environment/ Envirocon Joint Venture (FE JV). The purpose of this plan is to describe how vibration from the project activity will be monitored and managed during remedial activities at the Kreher Park, Copper Falls Aquifer, and Upper Bluff/Filled Ravine portions (Phase 1 Project Area) of the Ashland/Northern States Power Lakefront Site in Ashland, Wisconsin (Site). This *VMP* is prepared, as described, in the *Phase 1 Remedial Design Work Plan - Ashland/NSP Lakefront Site* (*RD Work Plan*) (Burns & McDonnell, 2012). Figure 1 illustrates the Site location.

Remedial activities will include the following:

- Excavation of contaminated soil;
- Excavations associated with installation of the shoreline braced sheet pile wall and a soil-bentonite cutoff wall to complete the containment of Kreher Park;
- Contaminated material transport to the thermal desorption system area;
- Contaminated material transport off-site;
- Wastewater collection and treatment;
- Contaminated material processing, including us of the medium temperature thermal desorption (MTTD) to treat contaminated materials; and
- Backfilling excavations.

Vibration will be monitored and managed throughout the above activities. Prior to the remediation activities at the Site, baseline conditions, the criteria of vibration evaluation, and a Site Vibration Monitoring Program will be established. This program is prepared by an expert in vibration analysis who reviews the specific activities and site conditions to develop the program details including:

- Identification of potentially affected structures;
- Scopes of the pre- and post-project inspections of those structures;
- Monitoring equipment coverage and placement;
- Field monitoring scope;
- Identification of potential exceedances;
- A protocol of appropriate avoidance and mitigation actions; and
- Other details.

Vibra-Tech Engineers (Vibra-Tech) has been contracted to perform the program development for the Site. The Site Vibration Monitoring Program prepared by Vibra-Tech is provided in Appendix A.

1.2 Scope of Work

Subsequent sections of this *VMP* describe:

- Building inspections;
- Development of vibration evaluation criteria;
- Deployment and operation of vibration monitoring equipment;
- Outline alert and action levels and response activities;
- Reporting procedures; and
- Communication plans for the public.

1.3 Plan Objectives

The objectives of the *VMP* are the following:

- Document the baseline and post-project condition of potentially at-risk structures adjacent to the Site;
- Analyze the planned activities and the Site, develop the criteria for vibration evaluation, and establish the Site Vibration Monitoring Program including monitor locations, operation parameters, and data collection;
- Provide guidelines to monitor vibration during remediation activities and evaluate the field data in real-time to assist in making appropriate Site management and communication decisions; and
- Document the vibration monitoring and management effort in a final report after project activities are essentially complete.

During the RD phase of the project, various plans will be developed that support the remedial action (RA) part of the project (i.e., the field work). Individual work elements for the RD/RA are described in other stand-alone, but correlated plans, including:

- *Ashland Lakefront RD/RA Project – Technical Execution Plan* (FE JV, 2012)
- *Remedial Action Quality Assurance Project Plan – Revision 1* (FE JV, 2014a)
- *Remedial Action Site Specific Health and Safety Plan* (*RA HASP*) (FE JV, 2014b)
- *Performance Standard Verification Plan* (FE JV, 2014c)
- *Construction Quality Assurance Plan* (FE JV, 2014d)
- *Noise Management Plan* (FE JV, 2014e)
- *Air Management Plan* (FE JV, 2014f)
- *Remedial Action Waste Management Plan* (FE JV, 2014g)
- *Erosion Control and Storm Water Management Plan* (FE JV, 2014h)

2 Overview of the Vibration Management Plan

Vibration monitoring at the Site will be conducted throughout the remedial activities to evaluate the effect of project-generated vibration on potentially at-risk adjacent structures. During the project, certain activities may result in vibrations that could affect the surrounding community. These may include driving sheet piling, installing soil-bentonite cutoff wall, jack hammering, operating large earthmoving equipment, excavation and backfill activities, and during MTTD unit operation. To manage vibration and its potential effects at the site, the *VMP* includes the following elements:

- A pre-project inspection of structures adjacent to the planned activities;
- Development of the criteria of evaluation specific to this site;
- Establishing the Site Vibration Monitoring Program to address vibration monitoring details for the site including locations of appropriate instrumentation, methods of data collection, and timing of essential tasks;
- Establishing an alert and action plan including communications and response protocols;
- Procedures for the vibration monitoring during remediation field activities, evaluating the data, and managing criteria exceedances and responses;
- A post-project inspection of structures adjacent to project activities; and
- A final report on the vibration monitoring at the site.

Under certain circumstances, vibration can be a nuisance to the public and could potentially affect certain buildings and structures by causing property damage. Although the risk is not great, vibration has been shown to potentially affect building foundations by exacerbating certain weaknesses of structures within the zone of its effect. Cosmetic effects such as plaster cracks, broken windows, etc. can impact area building owners/occupants negatively. By documenting the condition of various foundations and other characteristics of potentially affected buildings before and after remedial activities, the effect or lack of effect of the project can be evaluated.

2.1 Applicable Rules and Regulations

There are few specific criteria set forth in federal, state, or local rules and regulations. Wisconsin Administrative Code (Wis. Admin. Code) Chapter SPS 307 *Explosives and Fire Works* addresses blasting vibrations appropriate to mines and quarries. There are no explosives used on this project, therefore, this regulation is not directly applicable.

The City of Ashland addresses vibration requirements in its Unified Development Ordinance (City of Ashland, 2012) Section 7.1 F. The project is considered a temporary construction activity; therefore, the vibration restrictions noted in the ordinance Section 7.1 F, paragraph 1, do not apply to the project activities.

2.2 Baseline and Post-Construction Structure Inspections

The project activities in Kreher Park as depicted on Figure 2 are fairly isolated from potentially affected buildings and structures. Activities taking place on the Upper Bluff are closer to area structures and buildings therefore, have greater potential to impact them. Structures highlighted in the Parcel ID Map (Figure 3) have been identified as those potentially affected by project activities. Inspections are planned as indicated on Figure 3.

Prior to project activities commencing and as the project is completed, building owners and occupants will be contacted to arrange a convenient inspection appointment. Inspections will not be performed unless permission is granted by the owner/occupant. Inspections are targeted to include the exterior on all highlighted buildings on Figure 3 and the interior of the buildings shaded red. If allowed by the owner/occupant, the blue shaded buildings will also have interior inspections performed to provide additional information.

Exterior conditions of each structure will be documented with digital photographs and recorded audio narrative when appropriate. When performed, interior inspections will consist of documenting the physical condition of each structure by recorded audio narrative and augmented with digital photographs, as necessary. The inspections will not address the structural integrity of the buildings; however, inspections will focus on a visual observation of any existing defects, such as cracks in the foundation, exterior/interior walls, floors and ceilings. The pre-project inspection will be considered in the development of the Site Vibration Monitoring Program and addressed in Section 2.3.

2.3 Vibration Criteria Development and Development of the Site Vibration Monitoring Program

An analysis of the planned activities, the site characteristics, the pre-construction baseline inspection report, and other information will be performed by or under the supervision of a Professional Engineer knowledgeable in the science of vibration. Vibra-Tech has been contracted to prepare the Site Vibration Monitoring Program. The result of the analysis will be characterization of the potential effects on identified at-risk structures and establishment of the Site Vibration Monitoring Program. To develop this plan, the following will be performed:

- Review the site configuration, soil profile data obtained from soil borings, and other databases;
- Estimate peak ground vibration levels at various distances based on operating rated energy of the vibratory equipment and activities;
- Calculate ground vibration induced soil shear strain based on the shear wave propagation velocity and predicted peak particle velocity;
- Develop vibration criteria upon which to evaluate collected data including potential nuisance thresholds and potential damage thresholds;

- Develop the Site Vibration Monitoring Program including placement of data collection equipment (including seismographs and, as needed, analog crack gauges), timing, and operation and maintenance requirements for the equipment; and

- Develop the alert, action and response protocols at the Site.

The Site Vibration Monitoring Program is provided in Appendix A.

2.4 Implementing the Site Vibration Monitoring Program

Performing the vibration monitoring at the Site will follow the Site Vibration Monitoring Program as noted in Section 2.3. Individuals at the site who are responsible for oversight and performance of vibration monitoring and management are:

- **Project Superintendent:** has overall responsibility for vibration monitoring and management at the site.

- **Vibration Monitoring Manager (Site Technician):** has responsibility to perform or delegate the daily tasks needed to implement the Site Vibration Monitoring Program. This includes:

  - Install, monitor, and remove digital seismographs and analog crack gauges in accordance with the plan and field activities of the day;

  - Download and review the collected vibration data regularly and be responsible for compiling field documentation over the course of the project;

  - Monitor data and evaluate any approaches or exceedances of the action and alert levels;

  - Initiate communications and protocol in the appropriate circumstances; and

  - Maintain the vibration monitoring and associated equipment and consult with any appropriate service providers as needed to maintain the monitoring program.

2.4.1 Seismographs

The site will be monitored by four continuously monitoring digital seismographs to document vibrations associated with project activities. Potentially, the locations may be adjusted; however, Figure 3 shows the locations of the four seismographs. The coverage accounts for two residential areas, the Best Western Hotel and Our Lady of the Lake Church. The seismographs will measure peak particle velocities in three mutually perpendicular directions. The data are saved electronically, are part of the field record, and provide a record of the monitoring time for future review.

The Site vibration monitoring may show the potential to exceed certain developed thresholds during certain activities. Table 2-1 provides the limits and trigger levels.

Table 2-1

Seismograph Locations, Limits, and Trigger Levels[1]

Seismograph#	Location	Limit (inch/second)	Trigger Level (inch/second)
#1	Best Western	0.5	0.4
#2	Residential	0.5	0.4
#3	Our Lady of the Lake Church	0.3	0.2
#4	Residential	0.5	0.4

1. Information provided in the Site Vibration Monitoring Program, Table 12

Prepared by: AKM
Checked by: BMS1

In the event that the trigger level is approached and/or exceeded, the seismographs can be programmed to initiate a text message or email alert. Response and actions are described in Section 3.

2.4.2 Crack Gauges

Crack gauges may also be employed on cracks identified as appropriate in the pre-project inspection in conjunction with permission of property owners/occupants. These gauges show changes in cracks in two dimensions and serve as on-the-spot monitoring in real time of cracks that potentially may be affected by project activities. The types of cracks that would be most likely to be selected for monitoring would be significant cracks (i.e., larger than hairline) in foundations. Cracks will be documented in the pre- and post-construction inspection reports.

2.4.3 Field Documentation

A Field Log Book and other documentation (calibration field forms and data summaries) will be maintained by FE JV throughout the project. The following is a list of information that will be recorded and/or maintained:

- Description of construction activities conducted during instances where either the alert or action level was exceeded.
- Corrective actions conducted due to exceedance of a threshold or an action level.
- Vibration monitoring equipment installation, operation and removal dates.
- Vibration monitoring equipment calibration dates and results.
- Unusual situations which may affect monitoring results.

2.4.4 Calibration and Maintenance of System

Instrument calibrations will be performed in accordance with manufacturers' specifications for each piece of equipment. Copies of manufacturer's instrument manuals will be kept on-site as part of the *VMP*. Standard spare parts and consumables for each piece of equipment will be maintained during the Site activities.

2.5 Action Levels and Response

FE JV will develop a two-tiered approach to evaluate site conditions based on results of the vibration monitoring data. The approach first involves developing alert and action levels. The alert and action levels will be based on maximum vibration levels to be established in the criteria development as described in Section 2.3. If an exceedance of an alert or action level should occur, the approach then calls for response actions that will follow a set procedure to determine the potential cause of the exceedance, and to use this information to develop appropriate mitigation measures.

Upon receiving an alert or action message, the Vibration Monitoring Manager, or another individual delegated with those duties, shall notify the FE JV Project Superintendent and initiate a change in Site Condition (Section 2.5.1).

2.5.1 Categorical Site Conditions

Real-time vibration monitoring data will be used to evaluate site conditions on a continuous basis. These data will allow site personnel to adequately respond to periods of elevated vibrations in a timely manner. The Site vibration conditions will be categorized as follows:

- Site Condition Acceptable will be considered to be the general Operational Condition. During this condition, activities will continue as planned and all short-term vibration monitoring results will indicate that levels are below the applicable alert levels.

- Site Condition Alert will be initiated when vibration levels reach an alert level according to the Site Vibration Monitoring Program.

- Site Condition Action will be initiated when vibration levels reach an action level according to the Site Vibration Monitoring Program.

3 Reporting

The Site vibration monitoring will be documented and reported by the following: daily field reports; weekly vibration data summaries; exceedance notifications and responses; and an overall end of project report. Daily field reports will include exceedance notifications [documented on the Exceedance Documentation Report, which is located in Appendix B, and will be prepared within 24 hours of an incident. Weekly vibration data summaries will include information that has been collected for the week and to date that will facilitate communication with stakeholders on an on-going basis. At the end of remediation activities and vibration monitoring, an overall final report will be assembled.

3.1 Daily Field Reports

FE JV will provide daily field reports to the Project Superintendent and other site personnel as needed in an electronic format. The daily field report will be completed by the on-site field Site Technician and/or other site personnel. Information in the daily field report will include the following information:

- Daily potential vibration-causing activities on-site;
- Daily seismograph readings;
- Calibrations and/or maintenance of vibration monitoring equipment;
- Notes of concern or incidents related to instrumentation and/or vibration quality; and
- Exceedance notifications (if applicable).

Conclusions of daily field reports will be discussed at the daily morning health and safety tailgate meetings described in the *RA HASP*.

3.2 Weekly Vibration Data Summaries

Weekly project summaries of the real-time vibration monitoring data will be completed by the Site Technician and available to the Project Superintendent. Data will include seismograph results. The summaries will be supplemented with notations of any exceedance of alert and/or action levels and associated management responses and/or operational modifications. The report will also include a copy of any Exceedance Documentation Forms that were completed for the week.

Conclusions from the weekly project summaries will be used to evaluate and plan continued site activities during routine project meetings.

3.3 Final Vibration Management Program Report

At the conclusion of the project, FE JV will prepare an overall final project report encompassing all inspections, pre-site work plans, all field data and reports, documentation of any alerts, actions, responses, and evaluations, and any final paperwork completing the total record of the program. This report will be part of the overall project documentation.

4 Public Communication and Involvement Program

A Public Communication and Involvement Program will be implemented to provide timely and accurate information about remediation activities at the Site. Communication efforts will be specifically directed to the following entities:

- Residents and business owners close to the Site;
- Local health department; and
- Local officials.

Several communication methods may be used to provide information to the community about Site activities. These may include:

- NSPW communications website;
- Letters;
- Brochures (will include contact information);
- Periodic community meetings; and
- Door-to-door contacts with residents, as necessary.

Each citizen complaint or concern associated with vibrations from the activities at the Site received by the City of Ashland, NSPW, or FE JV personnel at the Site will be evaluated on a case-by-case basis. The data recorded corresponding to specific time intervals for which the concern or compliant is made will be evaluated, addressed appropriately, and documented as part of the field record.

5 References

Burns & McDonnell Engineering Company, Foth, 2012. *Phase I Remedial Design Work Plan – Ashland/NSP Lakefront Site*.

City of Ashland, 2012. *Unified Development Ordinance*.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2012. *Ashland Lakefront RD/RA Project – Technical Execution Plan.* February 2012.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014a. *Remedial Action Quality Assurance Project Plan – Revision 1* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014b. *Remedial Action Site Specific Health and Safety Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014c. *Performance Standard Verification Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014d. *Construction Quality Assurance Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014e. *Noise Management Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014f. *Air Management Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014g. *Remedial Action Waste Management Plan* – Ashland/NSP Lakefront Site. April 2014.

Foth Infrastructure & Environment/Envirocon Joint Venture, 2014h. *Erosion Control and Storm Water Management Plan* – Ashland/NSP Lakefront Site. April 2014.

United States District Court, Western District of Wisconsin. *United States of America and the State of Wisconsin (Plaintiff) v. Northern States Power Company (Defendant)*. Opinion and Order 12-cv-565-bbc. 19. October 2012.

U.S. Environmental Protection Agency, 2010. *Record of Decision.* September 2010.

URS, 2008. *Feasibility Study – Ashland/Northern States Power Lakefront Superfund Site.* December 2008.

Figures

SOURCE OR NOTES:
1. Coordinate System - WI83-NF
2. USGS 1:24K DRG: Ashland West, WI

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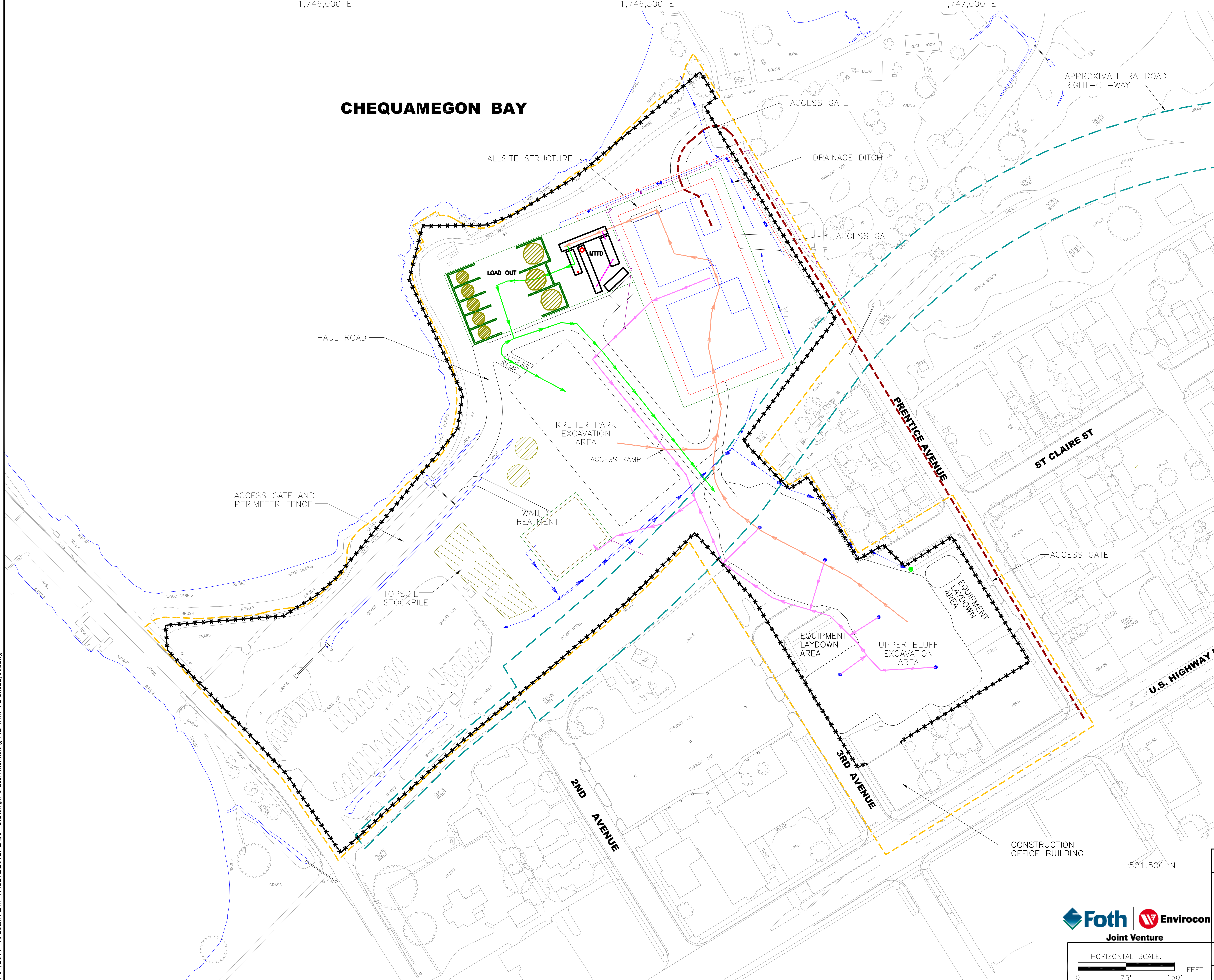
Joint Venture

This drawing is neither a legally recorded map nor a survey and is not intended to be used as one. This drawing is a compilation of records, information and data used for reference purposes only.

0 1,000 2,000 Feet

NORTHERN STATES POWER COMPANY		
FIGURE 1 SITE LOCATION MAP VIBRATION MANAGEMENT PLAN ASHLAND/NSP LAKEFRONT SITE		
Date: APRIL 2014	Revision:	
Drawn By: ADM	Checked By: BDS	Scope: 12X001

04/07/2014 - 10:16am ADM1 X:\GB\IE\2012\12X001\GIS\dwg\Vibration Monitoring Plan\VMP F1 SiteLocation.dwg



LEGEND

- EXISTING BUILDING
- EXISTING ROADWAY
- EXISTING SHORELINE/DRAINAGE
- EXISTING CULVERT
- EXISTING TREE/BRUSH
- PHASE 1 PROJECT AREA
- SOIL EXCAVATION AREA
- PROPOSED BUILDING
- PERIMETER FENCE WITH SILT FENCE ATTACHED
- DRAINAGE DITCH
- TOPSOIL STOCKPILE AREA
- DEWATERING PIPE
- GROUNDWATER PUMPING WELL
- OFF-SITE DISPOSAL ROUTE
- UNTREATED SOIL ROUTE
- TREATED SOIL ROUTE
- WASTE WATER DISCHARGE PIPE
- WASTE WATER DISCHARGE MANHOLE
- TREATED SOIL STOCKPILE

NOTES:

1. Coordinate System – WI83-NF

   This drawing is a 3D photogrammetric survey of the Ashland NSP Lakefront Site in Ashland Wisconsin. It is a compilation of developed 3D GIS layers, records, and data to be used for site analysis. Developed data was mapped in accordance with the AC-18B mapping standards.

2. Map base developed from October 12, 2012 imagery.

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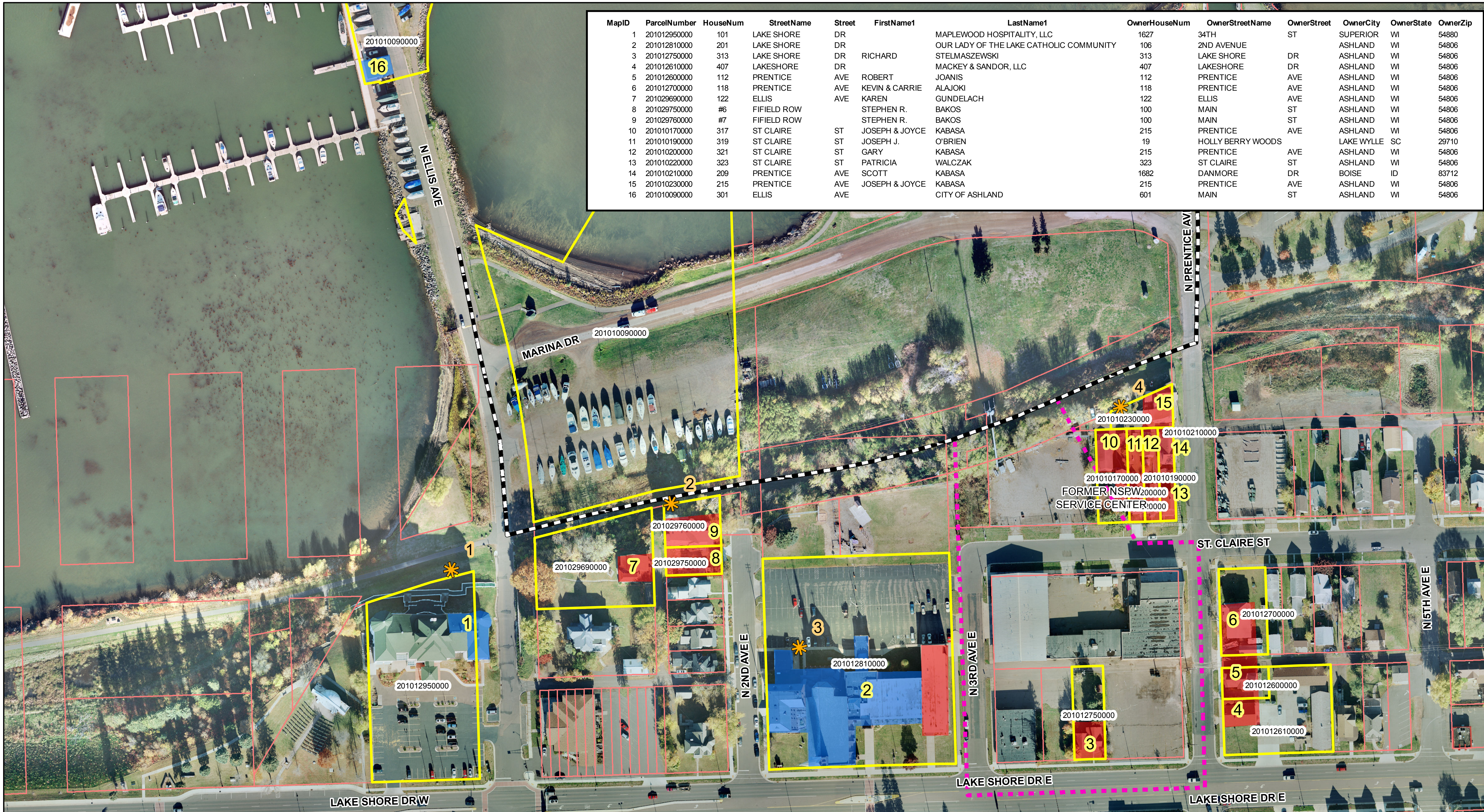
HORIZONTAL SCALE: 0 — 75' — 150' FEET

NORTHERN STATES POWER COMPANY		
FIGURE 2 SITE LAYOUT VIBRATION MONITORING PLAN ASHLAND/NSP LAKEFRONT SITE		
Date: APRIL 2014	Revision:	
Drawn By: ADM	Checked By: BDS	Scope: 12X001

Apr 07, 2014 - 10:25am ADM1 X:\GB\IE\2012\12X001\GIS\dwg\Vibration Monitoring Plan\VMP F2 SiteLayout.dwg

MapID	ParcelNumber	HouseNum	StreetName	Street	FirstName1	LastName1	OwnerHouseNum	OwnerStreetName	OwnerStreet	OwnerCity	OwnerState	OwnerZip
1	201012950000	101	LAKE SHORE	DR		MAPLEWOOD HOSPITALITY, LLC	1627	34TH	ST	SUPERIOR	WI	54880
2	201012810000	201	LAKE SHORE	DR		OUR LADY OF THE LAKE CATHOLIC COMMUNITY	106	2ND AVENUE		ASHLAND	WI	54806
3	201012750000	313	LAKE SHORE	DR	RICHARD	STELMASZEWSKI	313	LAKE SHORE	DR	ASHLAND	WI	54806
4	201012610000	407	LAKESHORE	DR		MACKEY & SANDOR, LLC	407	LAKESHORE	DR	ASHLAND	WI	54806
5	201012600000	112	PRENTICE	AVE	ROBERT	JOANIS	112	PRENTICE	AVE	ASHLAND	WI	54806
6	201012700000	118	PRENTICE	AVE	KEVIN & CARRIE	ALAJOKI	118	PRENTICE	AVE	ASHLAND	WI	54806
7	201029690000	122	ELLIS	AVE	KAREN	GUNDELACH	122	ELLIS	AVE	ASHLAND	WI	54806
8	201029750000	#6	FIFIELD ROW		STEPHEN R.	BAKOS	100	MAIN	ST	ASHLAND	WI	54806
9	201029760000	#7	FIFIELD ROW		STEPHEN R.	BAKOS	100	MAIN	ST	ASHLAND	WI	54806
10	201010170000	317	ST CLAIRE	ST	JOSEPH & JOYCE	KABASA	215	PRENTICE	AVE	ASHLAND	WI	54806
11	201010190000	319	ST CLAIRE	ST	JOSEPH J.	O'BRIEN	19	HOLLY BERRY WOODS		LAKE WYLLE	SC	29710
12	201010200000	321	ST CLAIRE	ST	GARY	KABASA	215	PRENTICE	AVE	ASHLAND	WI	54806
13	201010220000	323	ST CLAIRE	ST	PATRICIA	WALCZAK	323	ST CLAIRE	ST	ASHLAND	WI	54806
14	201010210000	209	PRENTICE	AVE	SCOTT	KABASA	1682	DANMORE	DR	BOISE	ID	83712
15	201010230000	215	PRENTICE	AVE	JOSEPH & JOYCE	KABASA	215	PRENTICE	AVE	ASHLAND	WI	54806
16	201010090000	301	ELLIS	AVE		CITY OF ASHLAND	601	MAIN	ST	ASHLAND	WI	54806



SOURCE OR NOTES:

1. Coordinate System - WI83-NF
2. Former NSPW Service Center to be demolished.
3. The numbered buildings are suggested vibration inspection locations. Final selection to be determined by vendor.

LEGEND

- Approximate Seismograph Location
- Selected Parcels
- Kreher Park Boundary
- Upper Bluff and filled Ravine Boundary
- Parcels

Building Inspections

- Exterior
- Exterior and Interior

This drawing is neither a legally recorded map nor a survey and is ot intended to be used as one. This drawing is a compilation of records, information and data used for reference purposes only.

0 75 150 Feet

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NORTHERN STATES POWER COMPANY

FIGURE 3

PARCEL ID MAP
VIBRATION MONITORING PLAN
ASHLAND/NSP LAKEFRONT SITE

Date: APRIL 2014	Revision Date:

Drawn By: DAT	Checked By: AKM	Scope: 12X001

Path: X:\GB\IE\2012\12X001\GIS\mxd\Vibration Monitoring Plan\Parcels_AOI_Mar2014.mxd Date: 4/2/2014

Appendix A

Site Vibration Monitoring Program
(prepared by Vibra-Tech Engineers)

January 16, 2014

VibraTechinc.com

9117 Leesgate Road
Suite 100
Louisville, KY 40222
Phone 502.326.4144
Fax 502.326.4155

Mr. Alan Buell
Envirocon Inc.
P.O Box 16655
Missoula, MT 59808

Re: Vibratory Equipment Induced Ground Vibration Monitoring Program
for Soil Remediation at Ashland/Northern State Power Company Lake Front Site,
Ashland, Wisconsin

Dear Mr. Martin:

This letter reports the vibration monitoring plan for the above referenced project. This report was prepared based on the following information:

- Project area layout with historical features, prepared by Foth dated October 2012.
- Site geotechnical investigation report, by Foth / Envirocon joint venture (FE JV), dated May 2013.
- Vibratory equipment specification utilized in the project provided by (FE JV).
- Project form of proposal, Ashland Lakefront (RFP#JMW-001-ALSS), pages 35-55 provided by Foth.

<u>Objectives:</u>

This report summarizes the vibration monitoring plan for Phase 1 of soil Remedial Action at the Ashland/Northern States Power Company (NSPW) Lakefront Site. The Site is located in Ashland, Wisconsin, along the southern shore of Chequamegon Bay, which is part of southwestern Lake Superior.

The Phase 1 of the upland portion of the project area is bounded to the north and south by the Chequamegon Bay shoreline and Lakeshore Drive/U.S. Highway 2, respectively. The east and west of the site is bounded to the Prentice and Ellis Avenues, respectively. In accordance with the project area layout plan, the abandoned Ashland Wastewater Treatment Plant (WWTP) located along the Chequamegon Bay shoreline and the area is part of the Kreher Park now. In addition, the site includes the former railroad corridor and former NSPW Service Center located near the corner of Lakeshore Drive/U.S. Highway 2 and Prentice Avenue .

The soil remediation activities includes:

- Removal of all former MGP structures.
- Excavation of all contaminated soil above levels that would support unrestricted use of the property.
- Pre-treatment handling and sorting of excavated material
- Backfilling of excavated areas with treated soil. The backfilling will be placed in 12 inches layers and mechanically compacted to the minimum density of 95% Standard Proctor.
- Construction of a bulkhead wall consisting sheet piles along shoreline
- Installation of a soil-bentonite cutoff wall around the inland section of the Kreher Park containment boundaries.
- Installation of temporary sheeting or shoring along Clair Street

The contractor plans to utilized the following construction equipment:

- ICE Model 55NF Vibratory pile driver
- Delmage D80-23 diesel impact hammer
- 84” pad foot vibratory compactor
- Large dozer
- Excavator
- Dump tucks

There is a concern that vibratory equipment including pile driving induced ground vibration may cause stress on adjacent structures. FE JV is the general contractor of the project. Vibra-Tech Engineers (VTE) was retained by Envirocon to analyze the effects of vibratory equipment induced ground vibration on the integrity of the adjacent structures and to establish a monitoring program for use during vibratory equipment activities.

The following scope of work is provided for this project:

- Review the site soil profile.
- Prediction of peak ground vibration levels at various distances based on vibratory equipments operating energy.
- Calculation of shear wave velocity based on the site standard penetration value (N-value).
- Calculation of developed soil shear strain based on the shear wave propagation velocity and predicted peak particle velocity.
- Comparison of predicted ground vibration with general vibration criteria established by various government agencies.
- Preparation of final report.

Ground Vibration Attenuation:

A) Pile Driving:

Vibration induced by pile driving is directly proportional to the square root of the vibratory energy and indirectly proportional to the distance from the construction activities. VTE utilized four different techniques to predict ground vibration amplitudes induced by pile driving activity at different distances. These techniques are:

I) Ground Vibration Attenuation Using Guideline Recommended by California Department of Transportation:

The California Department of Transportation published a guideline to predict ground vibration induced by construction activity. This publication contains a section for "*Vibration Amplitude Produced by Pile Driving Equipments* ". This guideline recommends using the following equation to predict the ground vibration level:

$PPV = (PPV_{Ref.}\ (25/D)^n)\ X\ (E_{equip} / E_{Ref})^{0.5}$ *(Impact Hammer)* ***(Equation 1-A)***
$PPV = (PPV_{Ref.}\ (25/D)^n)$*.....(Vibratory Hammer)* ***(Equation 1-B)***
Where:

PPV_{Ref} *= 0.65 in/sec for a reference pile driver at 25 ft(in/sec)*
D = Distance from pile driver to the receiver (ft)
E_{Ref} *= 36,000 ft-lbs (rated energy of reference pile driver)*
E_{equip}*= Rated energy of impact pile driver (ft-lbs)*
n = A value related to the vibration attenuation rate through ground
The following table shows the suggested value for "n":

Table 1- Suggested "n" value recommended by California Department of Transportation

Class	***Description of Soil Material***	***Suggested Value of "n"***
I	*Weak or Soft Soils- Loose soil, dry or partially saturated peat and muck, mud, loose beach sand, and dune sand, recently plowed ground, soft spongy forest or jungle floor, organic soil, topsoil. (shovel penetrates easily)*	*1.4*
II	*Competent Soils - Most sand, sandy clays, silty clays, gravel, silts, weathered rock. (can dig with shovel)*	*1.3*
III	*Hard Soils - Dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock. (Cannot dig with shovel, need pick to break up)*	*1.1*
IV	*Hard, Competent Rock – Bedrock, freshly exposed hard rock. (difficult to break with hammer)*	*1.0*

II) Ground Vibration Attenuation Using Euro-code 3, 1998:

For the purpose of predicting vibration intensities at varying distances from driven piles, the Euro-code recommends using the following empirical formula:

$$PPV = 0.1504 \frac{c\sqrt{E_h}}{D} \qquad \textbf{(Equation 2)}$$

Where:
PPV=Peak Ground Vibration (in/sec)
E_h=Hammer Energy (ft-lbs)
D=Distance (ft)
C = Soil Coefficient (0.75 for Stiff cohesive soil, medium dense granular, compact fill)

III) Ground Vibration Attenuation Using Scaled Distance:

Another technique that has been recommended by different researchers to predict the ground vibration induced by a known energy at different distances is "scaled distance". As a seismic wave travels outward from a source, it encounters ever-larger volumes of ground to vibrate, resulting in a reduction of energy per unit volume of material. This reduction of energy is directly proportional to a variable known as "scaled distance" (distance/square root of energy). The following equation represents the ground vibration attenuation based on scaled distance.

$$PPV = K\left[\frac{D}{\sqrt{E_h}}\right]^{-\alpha} \qquad \textbf{(Equation 3)}$$

Where:

PPV = Ground Peak Particle Velocity (in/sec)
K = Intercept at scaled distance =1
E_h = Hammer Energy (ft-lbs)
D = Distance from Pile (ft)
α = Slope (Soil dependence)

Woods and Jedele [1] did an extensive study to predict ground peak particle velocity based on scaled distance. The following graph represents the results of their work. The N- term represents the type of the soil. For competent soils (5 <$N_{\textit{Standard Penetration Value}}$<15); most sand, sandy clays, silt clay, gravel, silts, weathered rock (can dig with shovel), α = 1.525. For hard soils (15 <N *Standard Penetration*

1 Woods, R.D. and L.P. Jedele, "Energy-Attenuation Relationships from Construction Vibrations" Vibration Problems in geotechnical Engineering, Proceedings of symposium sponsored by the Geotechnical Engineering Division, ASCE, Detroit, Michigan (October 1985) pp 229-246

$_{Value}$<50); dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock (cannot dig with shovel), α= 1.108.

Based on the collected data in Figure 1, VTE developed the following equations to represent each curve:

$$PPV = 0.0142\left[\frac{D}{\sqrt{E_h}}\right]^{-1.525}$$ *(Soil Class II Competent Soils 5<N<15)* ***(Equation. 4)***

$$PPV = 0.0821\left[\frac{D}{\sqrt{E_h}}\right]^{-1.108}$$ *(Soil Class III Hard Soils 15<N<50)* ***(Equation.5)***

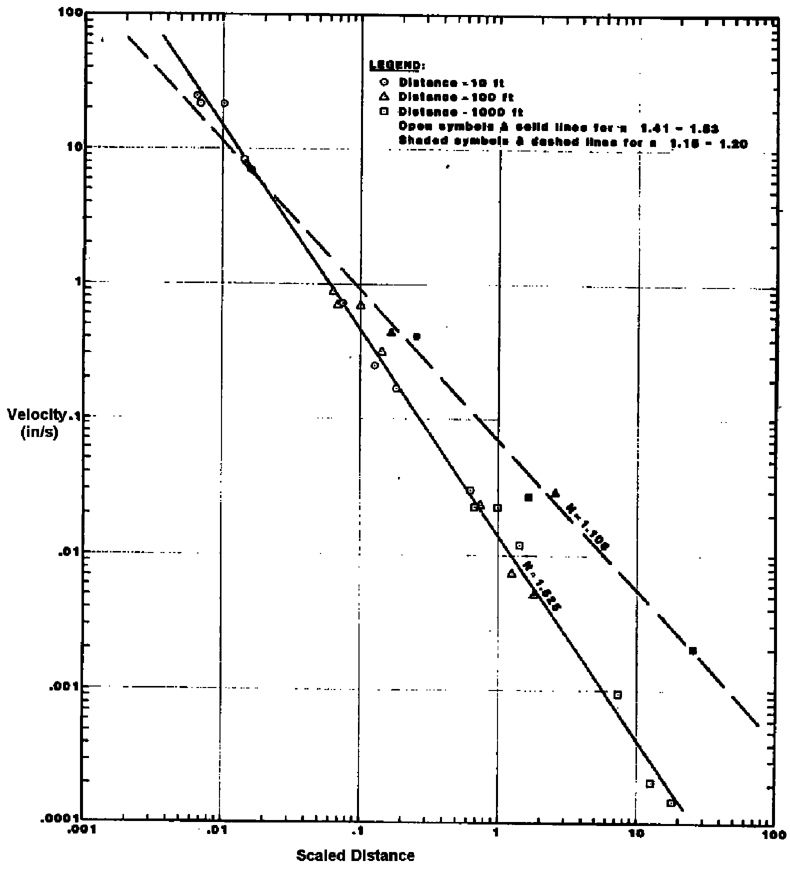

Figure 1- Scaled Distance vs. Peak Particle Velocity

IV) Ground Vibration Attenuation Using U.S. Department of Transportation:

For the purpose of construction vibration assessment, U.S. Department of Transportation utilized measured ground vibration data near various type of equipment including pile driving to develop vibration attenuation equation[2]. The vibration level propagation adjustment is in accordance to the following formula:

$PPV_{equipment} = PPV_{ref} X (25/D)^{1.5}$ ***(Equation.6)***

Where:
$PPV_{equipment}$ *=Peak Particle Velocity of the equipment adjusted for distance (in/s)*
PPV_{ref} *= Reference vibration level in 25 ft*
(PPV_{ref} *For Impact Hammer =1.518 upper limit & 0.644 Typical)*
(PPV_{ref} *For Vibratory Hammer =0.734 upper limit & 0.170 Typical)*

[2] Harris Miller & Hanson Inc. "Transit Noise and Vibration Impact Assessment", Federal Transit Administration, U.S. Department of Transportation, April 1995

The impact hammer that may be utilized in this project is Delmage diesel hammer model D 80-23. The maximum operating hammer energy is 212,420 ft-lbs. The following table shows the ground vibration induced by operation of this hammer at various distances:

Table 2-Ground Vibration Prediction Induced by Operation of a Delmage Single Impact Hammer Model D 80-23 (Hammer Energy=212,420 ft-lbs)

Distance (ft)	PPV (Hard Soils) (in/s)	PPV California Dept. of Transportation (in/s)	PPV Euro-code 3, 1998 (in/s)	U.S. Department of Transportation, Upper Level PPV (in/sec)	PPV Average (in/s)
10	5.72	4.33	5.20	6.00	**5.312**
15	3.65	2.77	3.47	3.27	**3.288**
20	2.66	2.02	2.60	2.12	**2.349**
25	2.07	1.58	2.08	1.52	**1.812**
30	1.69	1.29	1.73	1.15	**1.468**
35	1.43	1.09	1.49	0.92	**1.230**
40	1.23	0.94	1.30	0.75	**1.056**
45	1.08	0.83	1.16	0.63	**0.923**
50	0.96	0.74	1.04	0.54	**0.819**
55	0.87	0.66	0.95	0.47	**0.735**
60	0.79	0.60	0.87	0.41	**0.666**
65	0.72	0.55	0.80	0.36	**0.608**
70	0.66	0.51	0.74	0.32	**0.559**
75	0.61	0.47	0.69	0.29	**0.518**
80	0.57	0.44	0.65	0.27	**0.481**
85	0.53	0.41	0.61	0.24	**0.450**
90	0.50	0.39	0.58	0.22	**0.422**
95	0.47	0.36	0.55	0.20	**0.397**
100	0.45	0.34	0.52	0.19	**0.375**
120	0.36	0.28	0.43	0.14	**0.306**
140	0.31	0.24	0.37	0.11	**0.258**
160	0.27	0.20	0.32	0.09	**0.222**
180	0.23	0.18	0.29	0.08	**0.195**
200	0.21	0.16	0.26	0.07	**0.174**
220	0.19	0.14	0.24	0.06	**0.156**
240	0.17	0.13	0.22	0.05	**0.142**

The sheet piles may also be driven by an ICE vibratory hammer model 55NF, operating at maximum of 1,700 VPM with 489 hp (360 kw). Table 3 shows the ground vibration amplitude at various distances from the tip of the sheet pile.

Table 3-Ground vibration Prediction Induced by Operation of ICE 55NF Vibratory Hammer Operating at maximum speed of 1,700 VPM with 489 hp (360 kw) power

Distance (ft)	PPV California Dept. of Transportation (in/s)	PPV Euro-code 3, 1998 (in/s)	U.S. Department of Transportation, Upper Level PPV (in/sec)	PPV Average (in/s)
10	1.78	1.02	1.84	**1.545**
15	1.14	0.68	1.22	**1.014**
20	0.83	0.51	0.92	**0.753**
25	0.65	0.41	0.73	**0.597**
30	0.53	0.34	0.61	**0.494**
35	0.45	0.29	0.52	**0.421**
40	0.39	0.25	0.46	**0.367**
45	0.34	0.23	0.41	**0.325**
50	0.30	0.20	0.37	**0.291**
55	0.27	0.19	0.33	**0.264**
60	0.25	0.17	0.31	**0.241**
65	0.23	0.16	0.28	**0.222**
70	0.21	0.15	0.26	**0.206**
75	0.19	0.14	0.24	**0.192**
80	0.18	0.13	0.23	**0.179**
85	0.17	0.12	0.22	**0.168**
90	0.16	0.11	0.20	**0.159**
95	0.15	0.11	0.19	**0.150**
100	0.14	0.10	0.18	**0.142**
120	0.12	0.08	0.15	**0.118**
140	0.10	0.07	0.13	**0.101**
160	0.08	0.06	0.11	**0.088**
180	0.07	0.06	0.10	**0.078**
200	0.07	0.05	0.09	**0.070**
220	0.06	0.05	0.08	**0.063**
240	0.05	0.04	0.08	**0.058**

B) Vibratory Roller:

The ground vibration level induced by operation of the vibratory compactor is primarily the result of vibratory energy emitted to the soil by the compactor. The vibrator energy is directly proportional to the drum vibration amplitude and total dynamic loads applied to the soil. The following table shows the specification of a vibrator similar to the one that may be used in this project:

Table 4- 84" Pad foot vibratory compactor specification

Vibratory Roller	**Case Model 1102PD**
Max. Amplitude (in)	0.06
Max. Frequency (VPM)	1,680
Max. Centrifugal Force (lbs)	38,666
Operating Vibrating Weight (lbs)	13,668
Number of Drum	1
Vibrating roller drum width (in)	84.6

VTE used four methods to predict ground vibration at various distance from the vibratory compactor. The following describe each method:

I) Master's Thesis, Northwestern University, Evanston, Illinois:

The vibration induced by the vibratory roller is directly proportional to the drum energy[3]. According to reference 3, the energy emitted from the drum to the surrounding geology can be calculated by using the following formula:

$$(F+Wd)*2a <= E => (F+Wd) * 4a \qquad \textbf{(Equation.7)}$$

Where:

F=Centrifugal Force (lbs)
Wd=Drum Weight (lbs)
a=Nominal Amplitude (ft)
E = Estimated Energy = ft-lbs

[3] Frank Blais "Frequency and energy considerations for construction vibrations" Master's Thesis, Northwestern University, Evanston, Illinois, August 1993, pp 78-90

Based on the collected data from Reference 3 and the calculated vibratory roller energy, the ground vibration induced by operation of vibratory compactor can be calculated at various distances. The results are shown in Table 5:

II) British Standard BS 5228-2:2009:

Another technique used to predict ground vibration induced by operation of a vibratory rollers is the equation recommended in British Standard BS 5228-2:2009. The standard is a comprehensive document covering many aspects of prediction, measurement, assessment, and control of vibration from construction works. The following equation (Equation 8) is the British Standard BS 5228-2:2009 for prediction of ground vibration induced by operation of the vibratory compaction roller:

$$V = k_s \sqrt{n} \left[\frac{A}{R + w}\right]^{1.5}$$

(Equation 8)

Where:

K_s = 75 with a 50% probability of the vibration level being exceeded
K_s = 143 with a 33% probability of the vibration level being exceeded
K_s = 276 with a 5% probability of the vibration level being exceeded
n = the number of vibrating drums (ie 1 or 2)
A = the nominal amplitude of the vibrating drums (mm)
w = the width of the vibrating drum (m).
V = Peak Particle Velocity (mm/sec)
R = Distance from vibratory compactor (m)

III) Guideline Recommended by California Department of Transportation:

The California Department of Transportation guideline publication for prediction of ground vibration induced by construction activity, also recommend an empirical equation to predict vibratory compaction roller induced ground vibration at various distance. This guideline recommends using the following equation:

$PPV = (PPV_{Ref.}\ (25/D)^n)$.....(Vibratory Hammer) ***(Equation 9)***

Where:

PPV_{Ref} = 0.21 in/sec for a reference pile driver at 25 ft(in/sec)
D = Distance from vibratory roller to the receiver (ft)
n = 1.1

VI) Guideline Recommended by Australian Department of Maine Road (DMR):

The Australian Department of Maine Road (DMR), did an extensive field measurement of ground vibration induced by operation of heavy and very heavy classes of vibratory rollers from 1977 to 1985. Based on the recorded ground vibration data, a graph was produced giving guide to predict maximum ground Peak Particle Velocity (PPV) at various distance (D) from the vibratory compaction roller. VTE fit an equation to the graph. The following is the graph and fitted empirical equation for prediction of ground vibration induced by operation of single vibrating roller:

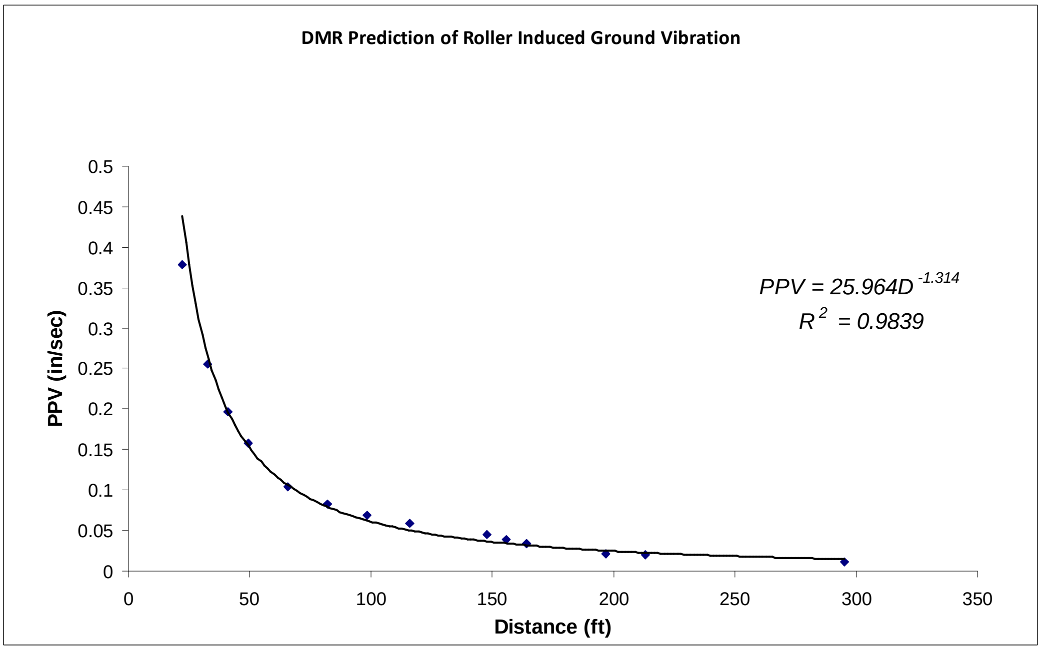

Figure 2- DMR Vibration Data Regression

Table 5 in following page show the predicted ground vibration induced by operation of the vibratory compaction rollers used in this project. The prediction utilized the aforementioned techniques.

Table 5 - Prediction of ground vibration induced by operation of CASE 110PD vibratory roller

D (ft)	BS 5228-2:2009 PPV (in/sec) 95% Confidence	DMR PPV (in/sec)	Frank Blais Thesis PPV (in/sec)	California Department of Transportation, PPV (in/sec)	Average PPV (in/sec)
10	1.72	1.27	1.24	0.58	**1.20**
15	1.17	0.75	0.70	0.37	**0.75**
20	0.86	0.51	0.47	0.27	**0.53**
25	0.67	0.38	0.35	0.21	**0.40**
30	0.54	0.30	0.27	0.17	**0.32**
35	0.45	0.25	0.22	0.15	**0.26**
40	0.38	0.21	0.18	0.13	**0.22**
45	0.32	0.18	0.15	0.11	**0.19**
50	0.28	0.15	0.13	0.10	**0.17**
55	0.25	0.14	0.12	0.09	**0.15**
60	0.22	0.12	0.10	0.08	**0.13**
65	0.20	0.11	0.09	0.07	**0.12**
70	0.18	0.10	0.08	0.07	**0.11**
75	0.16	0.09	0.08	0.06	**0.10**
80	0.15	0.08	0.07	0.06	**0.09**
85	0.14	0.08	0.06	0.05	**0.08**
90	0.13	0.07	0.06	0.05	**0.08**
95	0.12	0.07	0.05	0.05	**0.07**
100	0.11	0.06	0.05	0.05	**0.07**
105	0.10	0.06	0.05	0.04	**0.06**
110	0.10	0.05	0.04	0.04	**0.06**
115	0.09	0.05	0.04	0.04	**0.06**
120	0.08	0.05	0.04	0.04	**0.05**
125	0.08	0.05	0.04	0.04	**0.05**
130	0.08	0.04	0.03	0.03	**0.05**
135	0.07	0.04	0.03	0.03	**0.04**
140	0.07	0.04	0.03	0.03	**0.04**
145	0.06	0.04	0.03	0.03	**0.04**
150	0.06	0.04	0.03	0.03	**0.04**
155	0.06	0.04	0.03	0.03	**0.04**
160	0.06	0.03	0.03	0.03	**0.04**
165	0.05	0.03	0.03	0.03	**0.03**
170	0.05	0.03	0.02	0.03	**0.03**
175	0.05	0.03	0.02	0.02	**0.03**
180	0.05	0.03	0.02	0.02	**0.03**

<u>C)Hydraulic Excavator:</u>

The procedure recommended by the California Department of Transportation and the U.S. Department of Transportation are used to calculate ground vibration induced by large hydraulic excavator (large bulldozer). The following are the recommended equations:

PPV = (PPV$_{Ref.}$ (25/D)^n).....(Excavator) **(Equation 10)**

Where:

PPV_{Ref} = Reference (0.089 in/sec for large excavator & 0.003 in/sec for small excavator) at 25 ft(in/sec)

D = Distance from vibratory roller to the receiver (ft)

n = 1.1 (Recommendation by California Department of Transportation)

= 1.5 (Recommendation by U.S. Department of Transportation)

The following table shows the predicted ground vibration at various distance:

Table 6-Prediction of ground vibration at various distance induced by operation of a large hydraulic excavator (large bulldozer)

Distance (ft)	PPV California Dept. of Transportation	U.S. Department of Transportation	Average
	PPV (in/sec)	PPV (in/sec)	PPV (in/sec)
10	0.24	0.35	**0.30**
15	0.16	0.19	**0.17**
20	0.11	0.12	**0.12**
25	0.09	0.09	**0.09**
30	0.07	0.07	**0.07**
35	0.06	0.05	**0.06**
40	0.05	0.04	**0.05**
45	0.05	0.04	**0.04**
50	0.04	0.03	**0.04**
55	0.04	0.03	**0.03**
60	0.03	0.02	**0.03**
65	0.03	0.02	**0.03**
70	0.03	0.02	**0.02**
75	0.03	0.02	**0.02**
80	0.02	0.02	**0.02**
85	0.02	0.01	**0.02**

Vibration Criteria:

Vibration induced by the proposed vibratory equipment may have two types of effects on the integrity of the existing adjacent structures. First, excessive vibration may cause soil softening due to the increasing of pore water pressure and shear strain. This results in a lowering of the soil stiffness supporting the foundation and may cause settlement. Second, it may vibrate the structure and due to excessive vibration, damage the structural elements. The proceeding paragraphs review each cause:

A) Vibration Effects on Soil:

Soil vibration can cause a reduction in the void ratio of cohesionless soils and result in severe settlement. Ordinarily, the settlement will be small if the relative density of the soil is greater than 60%, but if the vibration is severe, settlement can occur until the relative density reaches nearly 80%[4]. Vibration in loose, saturated cohesionless soil can bring about liquefaction and failure.

The standard penetration resistance, N, is an indication of the density of cohesionless soil and of the strength of cohesive soil. Tables 7 and 8 have been proposed to describe density and strength from standard penetration test results.

Table 7- Relative Density of Sand-Standard Penetration Test (After Terzaghi and Peck[5])

Blows	Relative Density
0 – 4	Very loose
5 – 10	Loose
11 – 20	Firm
21 – 30	Very firm
31 – 50	Dense
51+	Very dense

[4] Introductory Soil Mechanic and Foundations, George F. Sowers 1979, pp 495

5 K. Terzaghi and Peck, Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley & Son, Inc., New York, 1968, pp. 341 and 347

Table 8- Consistency of Cohesive Soils-Standard Penetration Test
(After Terzaghi and Peck[5])

Blows	Consistency
0 – 1	Very soft
2 – 4	Soft
5 – 8	Firm
9 – 15	Stiff
16 – 30	Very stiff
31+	Hard

The tables in Appendix A of this report show the standard penetration data (N-Value) at various location of the site.

<u>Energy Transfer from Vibratory Equipment to Soil:</u>

The vibratory energy associated with the operation of construction equipment is imparted into surrounding soil by wave. As the wave propagates, a seismic shear stress is induced within the soil particles. The induced shear stress is directly proportional to the vibratory equipment energy. The shear stress near the vibratory equipment creates a large strain within the soil and causes a reduction in the shear modulus. This reduction in the shear modulus of the soil results in increased soil deformation. The graph on following page illustrates the reduction in the shear modulus as the induced soil shear strain is increased.

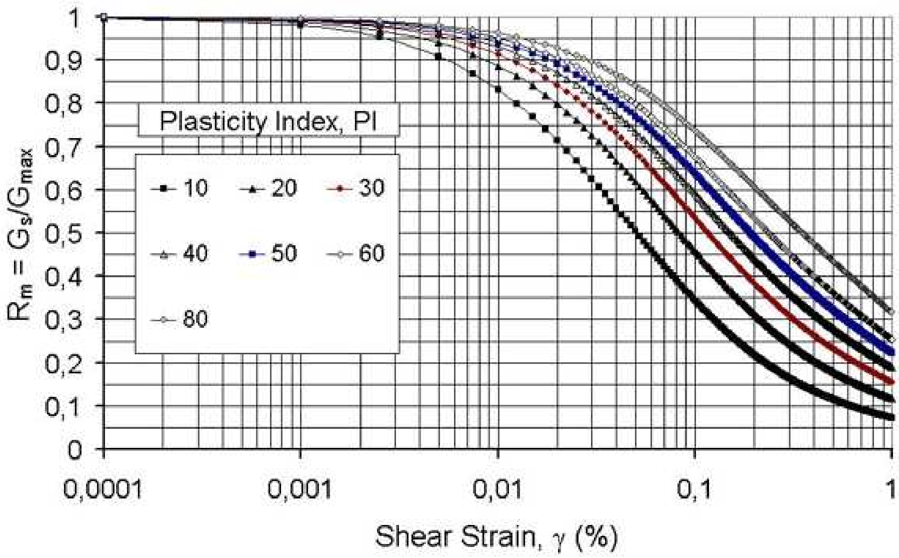

Figure 3 - Reduction of shear modulus as a function of shear strain in saturated sand[6]

According to Figure 3, at a shear strain level of 0.0005% there is no reduction in the shear modulus of the soil, however at 1.0% shear strain the shear modulus is only 5% of its original value. The reduction in shear modulus of elasticity will result in settlement. The following graph shows the relation between shear strain and vertical strain:

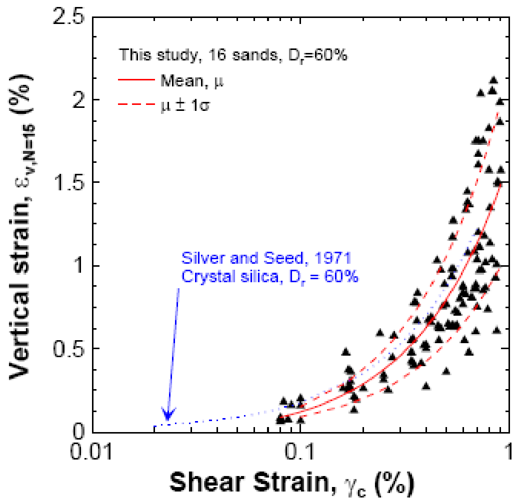

Figure 4 - Relation between soil shear strain and vertical strain based on simple shear testing of clean sand[7]

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[6] Dr. K. Rainer Massarsch, Presentation on " Deep Compaction of Granular Soils" at Zhejiang University Hangzhou, Pr China, "International Lecture Series on Geotechnical Engineering and its Development in the 21st Century", January 21, 1999.

According to Figure 4 at 0.01% shear strain the vertical strain is minimal. Also, Reference 8 cites numerous tests to determine the threshold shear strain, γ_{tv} for sand and clay. These tests have concluded that the threshold shear strain for sands is, γ_{tv} = 0.01 to 0.02% while for clay having PI=30 γ_{tv} = 0.04 to 0.09%[8].

This indicates that if the vibratory equipment-induced soil shear strain is less than γ_{tv}, no settlement should occur at adjacent structures.

Wave Propagation in Elastic Medium:

The propagation of all types of waves is a mechanism of transferring energy from one point to another without physical transfer of material between the points. The induced ground vibration associated with vibratory equipment is emitted to surrounding area by wave propagation. The shear strain induced by the wave energy in the soil can be calculated using the following equation:

$$\varepsilon = \frac{PPV}{V_S}$$ ***(Equation 11)***

Where:
ε=Soil Shear Strain
PPV=Peak Particle Velocity (in/sec)
V_S=Shear Propagation Velocity (in/sec)

It is important to distinguish clearly between wave propagation velocity *(V_S)* and the velocity of a particle in the stressed zone *(PPV)*. The above equation indicates that the strain level of a vibrating media is a function of the actual level of particle velocity acting on the media and the propagation velocity of the media.

Shear Wave Velocity:

In accordance with the wave propagation theory in an elastic medium (Equation 2), in order to calculate the soil shear strain resulting from pile driving operations, one requires the ground peak particle velocity *(PPV)* and soil shear wave velocity *(V_S).* The *PPV* is already predicted in the previous section (Tables 2,3,5,and 6). The following formula can be used to calculate the shear wave velocity based on standard penetration test and depth[9].

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[7] J.P. Stewart & D.H. Whang "Simplified Procedure to Estimate Ground Settlement from Seismic Compression in Compacted Soil", 2003 Pacific Conference on earthquake Engineering" University of California, Los Angles, Ca, Paper No. 046

[8] Chu-Chung Hsu and Mladen Vucetic "Volumetric Threshold Shear Strain for Cyclic Settlement" *Journal of geotechnical and geo-environmental engineering"* January 2004

[9] H. Bolton Seed, Robert T. Wong, I.M. Idriss, and Tokimatsu, "Moduli and Damping Factor for Dynamic Analysis of Cohesionless Soils" Journal of Geotechnical Engineering, Vol 112, No. 11, November 1986, pp 1016

$$V_S = 220N^{0.17}D^{0.2}$$ ***(Equation 12)***

Where:
V_S = Shear Wave Velocity ft/s
N = Standard Penetration Test (SPT- Value) Delivering 60% of Energy
D = Depth of the Soil (ft)

By utilizing equations 5 & 6 in combination with the SPT N-value data, the tables in Appendix A illustrate the results of N_{60} value, shear wave propagation velocity, and soil shear strain at Peak Particle Velocity (PPV) of 0.50 in/sec:

B) Structural Damage Criteria:

Vibration induced by construction activities may cause deformations or some form of distress in adjacent structures such as:

- Cracking
- Aggravation of existing cracks

Acceptable vibration criteria must take into account the following parameters:

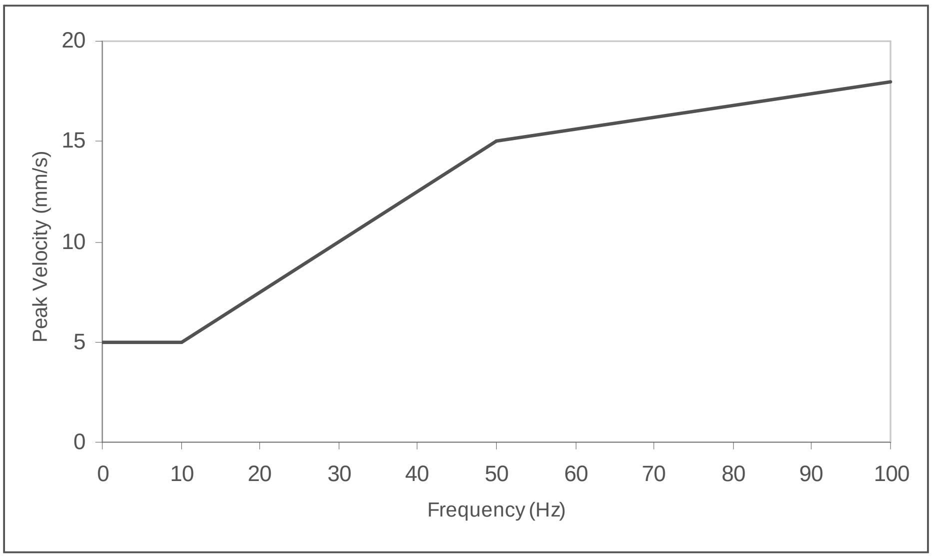
- Type and quality of the building material (especially its ductility)
- Type of construction
- Age of the structure
- Duration of the vibration effects
- Characterization of the vibration (frequency

The following are standard damage criteria established by various regulations:

Standard DIN 4150, Part 3 (1983)[10]*:*

The third part of standard DIN 4150 recommends the transient vibrations induced by blasting, pile driving, etc., and are to be limited in terms of maximum foundation velocities. The following graph illustrates the damage criteria for residential building categories.

Figure 5- Vibration velocity limit for residential structure (DIN 4150 part 3).



[10] German Inst. for Standards, DIN 4150, "Vibration in Civil Engineering Part 3, Effects on Structures" Draft, March 1983

Standard SN 640312[11]*:*

The association of Swiss Highway Engineers has established damage criteria for four different classes of buildings. The following tables show the structure categories and the recommended vibration limit:

Table 9-Structural Categories According to SN 64-312(from [11])

Structural Category	Definition
I	Reinforced-concrete and steel structures (without plaster) such as industrial buildings, bridges, masts, retaining walls, unburied pipelines; Underground structures such as caverns, tunnels, galleries, lined and unlined
II	Buildings with concrete floors and basement walls, above-grade walls of concrete, brick or ashlars masonry; ashlars retaining walls, buried pipelines; Underground structures such as caverns, tunnels, galleries, with masonry lining
III	Buildings with concrete basement floors and walls, above-grade masonry walls, timber joist floors
IV	Buildings which are particularly vulnerable or worth protecting

Table 10-Acceptance Criteria of SN 640312 for the Aforementioned Structural Categories[10]

Structural Category	**Source M**		**Source S**	
	f(Hz)	**V (mm/s)**	**f(Hz)**	**V (mm/s)**
I	10 to 30	12	10 to 60	30
	30 to 60	12 to 18	60 to 90	30 to 40
II	10 to 30	8	10 to 60	18
	30 to 60	8 to 12	60 to 90	18 to 25
III	10 to 30	5	10 to 60	12
	30 to 60	5 to 8	60 to 90	12 to 18
IV	10 to 30	3	10 to 60	8
	30 to 60	3 to 5	60 to 90	8 to 12
Source M: Machinery, Traffic, Construction Work				
Source S : Blasting Operation				

[11] Institution of Swiss Highway Engineering (VSS), Swiss Standard SN 640312, "Vibration Effects on Structures", VSS Secretariat Zurich, Nov. 1987

California Department of Transportation:

The California Department of Transportation recommend following vibration criteria for different type of structures:

Table 11- California DOT Guideline Vibration Damage Potential Threshold Criteria

Structure and Condition	Transient	Continuous/Frequent Intermittent
	Max PPV (in/s)	Max PPV (in/s)
Extremely fragile historic buildings, ruins, ancient monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1	0.5
Modern industrial/commercial buildings	2	0.5

Note: Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

Conclusions & Recommendation:

Due to the previous soil contamination at the former Ashland/Northern States Power Company, the existing soil needs to be excavated, replaced, and compacted. The soil excavation requires the installation of a series of sheet piles for soil retention and support of adjacent structures. The contractor plans to insert the sheet piles with a Delmage D80-23 diesel hammer or 55NF ICE vibratory pile driver. The newly placed fill material will be compacted with a 84" pad foot vibratory compactor. In addition a soil-bentonite cutoff wall will be installed around the inland section of the Kreher Park containment boundaries. The construction of the vertical barrier includes mixing of sodium bentonite with water to form a viscous slurry that is pumped into a trench during excavation to maintain the trench stability. The stable trench is then backfilled with a mixture of soil and slurry having a consistency of high slump concrete. Large dozer and hydraulic excavator utilized in construction of the barrier wall.

There is a concern that vibratory equipment including pile driving induced ground vibration may cause stress on adjacent structures. FE JV is the general contractor of the project. Vibra-Tech Engineers (VTE) was retained by Envirocon to analyze the effects of vibratory equipment induced ground vibration on the integrity of the adjacent structures and to establish a monitoring program for use during vibratory equipment activities.

Ground vibration induced by construction activities such as pile driving or soil compaction may have two types of effects on the integrity of adjacent properties. First, it may vibrate the structure, and due to excessive vibration, damage the structural elements. Second, excessive vibration may cause soil softening due to the increasing of pore water pressure and shear strain. This in turn results in lowering the soil stiffness supporting the foundation and may cause settlement or partial liquefaction.

The soil shear strain is directly proportional to the peak ground vibration induced during the vibratory equipment activities. The review of tables in Appendix A of this report reveal that the maximum soil shear strain is 0.0137% when peak particle velocity is 0.50 in/sec. Figure 4 shows that for cohesionless soil there would be no vertical strain when the shear strain is around 0.01% to 0.02%. Therefore, If ground vibration near the adjacent properties is less than 0.50 in/sec, there will be no soil settlement.

The nearby buildings are mainly residential type structure. Our Lady of Lake Catholic Church is located along U.S. Highway 2 and is approximately over 100 years old. The commercial structure to the west side of the remediation site is Best Western Hotel Chequamegon. It is recommended that ground vibration at locations illustrated in Figure 6 be monitored with a tri-axial seismograph. Appendix B shows the seismograph specification.

Figure 6- Seismograph Locations

The following table shows the maximum allowable vibration and trigger level for each locations. The seismographs should be programmed to record peak particle vibration at one minute interval. Once the peak vibration exceeds the pre-programmed trigger level, the vibration time history should be recorded for period of two seconds.

Table 12- Seismographs limits and trigger level

Seismograph #	Location	Limit (in/sec)	Trigger Level (in/sec)
#1	Best Western	0.5	0.4
#2	Residential	0.5	0.4
#3	Our Lady of Lake Catholic Church	0.3	0.2
#4	Residential	0.5	0.4

It is also recommended that the some of the existing cracks in the church structure be monitored with a mechanical crack gauge such as Avongaurd. The baseline recording of the crack gauges should be completed prior to any construction actives. Figures 7 show the recommended locations for installation of crack gauges:

Figure 7- Existing cracks in the church to be monitored with crack gages

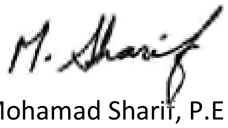
It is recommended that the existing condition of the adjacent structures and residential buildings be documented prior to any construction activities. Based on the existing condition of the structure proper monitoring may be needed.

It should be noted that the author is not registered as a professional engineer (PE) in the state of Wisconsin. However, he is registered as a professional engineer in the states of; Illinois, New York, New Jersey, Washington, Kentucky, North Carolina, South Carolina, Ohio, Pennsylvania, Delaware, Maryland, Michigan, and Florida.

We appreciate the opportunity to assist you with this project. If you have any questions or require additional information, please contact our office.

Sincerely,

VIBRA-TECH ENGINEERS, INC.



Mohamad Sharif, P.E (IL)
Senior Engineer / Structural Dynamic Analyst.

APPENDIX-A

Soil Data

Soil Shear Strain at Bore Hole No. SB-167

Depth to water table **z_{gwt} =** **11 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	117	117	0	117	10	1.70	1.3	1	1	1	22.7	Fill	374	0.0111
3	117	351	0	351	3	1.70	1.3	1	1	1	6.8		380	0.0110
5	117	585	0	585	2	1.70	1.3	1	1	1	4.5		392	0.0106
7	117	819	0	819	3	1.61	1.3	1	1	1	6.4		445	0.0094
9	117	1053	0	1053	2	1.42	1.3	1	1	1	3.8	SP	428	0.0097
11	117	1287	0	1287	15	1.28	1.3	1	1	1	25.6		617	0.0068
13	117	1521	125	1396	10	1.23	1.3	1	1	1	16.4		591	0.0070
15	117	1755	250	1505	22	1.19	1.3	1	1	1	34.8	SC-SM	691	0.0060
17	117	1989	374	1615	32	1.15	1.3	1	1	1	48.9	SM	751	0.0055
19	117	2223	499	1724	51	1.11	1.3	1	1	1	75.4	ML	827	0.0050
21	117	2457	624	1833	42	1.07	1.3	1	1	1	60.2	SC	812	0.0051
23	117	2691	749	1942	35	1.04	1.3	1	1	1	48.7	SM	797	0.0052
25	117	2925	874	2051	9	1.02	1.3	1	1	1	12.2	SP-SM	641	0.0065

Soil Shear Strain at Bore Hole No. SB-168

Depth to water table z_{gwt} = **21 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	117	117	0	117	4	1.70	1.3	1	1	1	9.1	Fill	320	0.0130
3	117	351	0	351	5	1.70	1.3	1	1	1	11.3		414	0.0101
5	117	585	0	585	4	1.70	1.3	1	1	1	9.1		442	0.0094
7	117	819	0	819	5	1.61	1.3	1	1	1	10.7		486	0.0086
9	117	1053	0	1053	27	1.42	1.3	1	1	1	51.0		666	0.0063
11	117	1287	0	1287	11	1.28	1.3	1	1	1	18.8	SP	585	0.0071
13	132	1551	0	1551	10	1.17	1.3	1	1	1	15.6	CL	586	0.0071

Soil Shear Strain at Bore Hole No. SB-169

Depth to water table **z_{gwt} = 19 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	107	107	0	107	3	1.70	1.3	1	1	1	6.8	Fill	305	0.0137
3	107	321	0	321	4	1.70	1.3	1	1	1	9.1		399	0.0105
5	107	535	0	535	5	1.70	1.3	1	1	1	11.3		459	0.0091
7	107	749	0	749	13	1.68	1.3	1	1	1	29.1	SC	576	0.0072
9	107	963	0	963	35	1.48	1.3	1	1	1	69.2		702	0.0059
11	107	1177	0	1177	21	1.34	1.3	1	1	1	37.5		658	0.0063
13	107	1391	0	1391	46	1.23	1.3	1	1	1	75.7		767	0.0054
15	107	1605	0	1605	11	1.15	1.3	1	1	1	16.8	CH	611	0.0068
17	107	1819	0	1819	99	1.08	1.3	1	1	1	142.4		901	0.0046
19	107	2033	0	2033	33	1.02	1.3	1	1	1	44.9	SC	757	0.0055
21	107	2247	125	2122	25	1.00	1.3	1	1	1	33.3	SM	734	0.0057
23	107	2461	250	2211	35	0.98	1.3	1	1	1	45.7		789	0.0053

Soil Shear Strain at Bore Hole No. SB-170

Depth to water table **z_{gwt} =** **19** **ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	107	107	0	107	10	1.70	1.3	1	1	1	22.7	Fill	374	0.0111
3	107	321	0	321	7	1.70	1.3	1	1	1	15.9		438	0.0095
5	107	535	0	535	3	1.70	1.3	1	1	1	6.8		420	0.0099
7	107	749	0	749	2	1.68	1.3	1	1	1	4.5		419	0.0099
9	107	963	0	963	2	1.48	1.3	1	1	1	4.0		431	0.0097
11	107	1177	0	1177	3	1.34	1.3	1	1	1	5.4		473	0.0088
13	107	1391	0	1391	4	1.23	1.3	1	1	1	6.6		506	0.0082
15	107	1605	0	1605	9	1.15	1.3	1	1	1	13.8	SC	591	0.0071
17	107	1819	0	1819	12	1.08	1.3	1	1	1	17.3		629	0.0066
19	107	2033	0	2033	18	1.02	1.3	1	1	1	24.5		683	0.0061
21	107	2247	125	2122	27	1.00	1.3	1	1	1	36.0	SM/GM	744	0.0056
23	107	2461	250	2211	41	0.98	1.3	1	1	1	53.5	SP	810	0.0051

Soil Shear Strain at Bore Hole No. SB-171

Depth to water table **z_{gwt} =** **15** **ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	107	107	0	107	9	1.70	1.3	1	1	1	20.4	Fill	367	0.0113
3	107	321	0	321	9	1.70	1.3	1	1	1	20.4		458	0.0091
5	107	535	0	535	7	1.70	1.3	1	1	1	15.9		486	0.0086
7	107	749	0	749	12	1.68	1.3	1	1	1	26.9		568	0.0073
9	107	963	0	963	11	1.48	1.3	1	1	1	21.7	SP	576	0.0072
11	107	1177	0	1177	27	1.34	1.3	1	1	1	48.3	CL	687	0.0061
13	107	1391	0	1391	27	1.23	1.3	1	1	1	44.4	SM/SC	700	0.0059
15	107	1605	0	1605	52	1.15	1.3	1	1	1	79.6	CH	796	0.0052
17	107	1819	125	1694	26	1.12	1.3	1	1	1	38.7	SC/SM	722	0.0058
19	107	2033	250	1783	18	1.09	1.3	1	1	1	26.1	SP	690	0.0060

Soil Shear Strain at Bore Hole No. SB-172

Depth to water table z_{gwt} = **29 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	107	107	0	107	7	1.70	1.3	1	1	1	15.9	Fill	352	0.0118
3	107	321	0	321	10	1.70	1.3	1	1	1	22.7		466	0.0089
5	107	535	0	535	3	1.70	1.3	1	1	1	6.8		420	0.0099
7	107	749	0	749	2	1.68	1.3	1	1	1	4.5		419	0.0099
9	107	963	0	963	2	1.48	1.3	1	1	1	4.0		431	0.0097
11	107	1177	0	1177	4	1.34	1.3	1	1	1	7.2		497	0.0084
13	107	1391	0	1391	28	1.23	1.3	1	1	1	46.1	SP-SM	705	0.0059
15	107	1605	0	1605	33	1.15	1.3	1	1	1	50.5	ML	737	0.0057
17	107	1819	0	1819	39	1.08	1.3	1	1	1	56.1	SC	769	0.0054
19	107	2033	0	2033	39	1.02	1.3	1	1	1	53.1	SP	779	0.0054
21	107	2247	0	2247	27	0.97	1.3	1	1	1	34.9	SC/SM	740	0.0056
23	107	2461	0	2461	65	0.93	1.3	1	1	1	80.4	SC/CH	868	0.0048
25	107	2675	0	2675	43	0.89	1.3	1	1	1	51.0	CL/SC	817	0.0051

Soil Shear Strain at Bore Hole No. SB-173

Depth to water table **z_{gwt} =** **35** **ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	107	107	0	107	12	1.70	1.3	1	1	1	27.2	Fill	386	0.0108
3	107	321	0	321	13	1.70	1.3	1	1	1	29.5		487	0.0086
5	107	535	0	535	10	1.70	1.3	1	1	1	22.7		516	0.0081
7	107	749	0	749	3	1.68	1.3	1	1	1	6.7		449	0.0093
9	107	963	0	963	2	1.48	1.3	1	1	1	4.0		431	0.0097
11	107	1177	0	1177	5	1.34	1.3	1	1	1	8.9		516	0.0081
13	107	1391	0	1391	24	1.23	1.3	1	1	1	39.5	SP	686	0.0061
15	107	1605	0	1605	26	1.15	1.3	1	1	1	39.8	SM	707	0.0059
17	107	1819	0	1819	52	1.08	1.3	1	1	1	74.8	SC	807	0.0052
19	107	2033	0	2033	60	1.02	1.3	1	1	1	81.6		838	0.0050
21	107	2247	0	2247	56	0.97	1.3	1	1	1	72.5		838	0.0050
23	107	2461	0	2461	45	0.93	1.3	1	1	1	55.6		816	0.0051
25	107	2675	0	2675	26	0.89	1.3	1	1	1	30.8	SM	750	0.0056

Soil Shear Strain at Bore Hole No. SB-174

Depth to water table z_{gwt} = **33 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	99	99	0	99	10	1.70	1.3	1	1	1	22.7	Fill	374	0.0111
3	99	297	0	297	6	1.70	1.3	1	1	1	13.6		427	0.0098
5	99	495	0	495	10	1.70	1.3	1	1	1	22.7		516	0.0081
7	107	709	0	709	4	1.70	1.3	1	1	1	9.1	SC/CL	472	0.0088
9	107	923	0	923	4	1.51	1.3	1	1	1	8.1		487	0.0086
11	107	1137	0	1137	9	1.36	1.3	1	1	1	16.4		572	0.0073
13	107	1351	0	1351	21	1.25	1.3	1	1	1	35.0		673	0.0062
15	107	1565	0	1565	22	1.16	1.3	1	1	1	34.1		689	0.0060
17	107	1779	0	1779	38	1.09	1.3	1	1	1	55.3		767	0.0054
19	122	2023	0	2023	27	1.02	1.3	1	1	1	36.8		732	0.0057
21	122	2267	0	2267	42	0.97	1.3	1	1	1	54.1		797	0.0052
23	122	2511	0	2511	35	0.92	1.3	1	1	1	42.8		780	0.0053
25	122	2755	0	2755	9	0.88	1.3	1	1	1	10.5		625	0.0067

Soil Shear Strain at Bore Hole No. SB-175

Depth to water table z_{gwt} = **35 ft**

Depth	Total Unit Weight	Total Stress	Pore Pressure	Effective Stress	Uncorrected Blow Count	SPT Correction Factors					Corrected Blow Count	Soil Type (USCS)	Shear Wave Velocity (ft/s)	Soil Shear Strain at 0.5 in/s (%)
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	117	117	0	117	11	1.70	1.3	1	1	1	24.9	Fill	380	0.0110
3	117	351	0	351	10	1.70	1.3	1	1	1	22.7		466	0.0089
5	117	585	0	585	5	1.70	1.3	1	1	1	11.3		459	0.0091
7	117	819	0	819	5	1.61	1.3	1	1	1	10.7		486	0.0086
9	117	1053	0	1053	3	1.42	1.3	1	1	1	5.7		459	0.0091
11	117	1287	0	1287	5	1.28	1.3	1	1	1	8.5		512	0.0081
13	117	1521	0	1521	6	1.18	1.3	1	1	1	9.4		538	0.0077
15	117	1755	0	1755	4	1.10	1.3	1	1	1	5.9		511	0.0082
17	117	1989	0	1989	4	1.03	1.3	1	1	1	5.5		518	0.0080
19	117	2223	0	2223	4	0.98	1.3	1	1	1	5.2		525	0.0079
21	117	2457	0	2457	7	0.93	1.3	1	1	1	8.7	SC	584	0.0071
23	117	2691	0	2691	12	0.89	1.3	1	1	1	14.2	CL	647	0.0064
25	117	2925	0	2925	44	0.85	1.3	1	1	1	49.9		814	0.0051

Soil Shear Strain at Bore Hole No. SB-159

Depth to water table			z_{gwt} =	5	ft									
Depth	**Total Unit Weight**	**Total Stress**	**Pore Pressure**	**Effective Stress**	**Uncorrected Blow Count**	**SPT Correction Factors**					**Corrected Blow Count**	**Soil Type (USCS)**	**Shear Wave Velocity (ft/s)**	**Soil Shear Strain at 0.5 in/s (%)**
z	g	σ_{vo}	u	σ_{vo}'	N_m	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$			
(ft)	(pcf)	(psf)	(psf)	(psf)	(blows/ft)						(blows/ft)			
0														
1	117	117	0	117	5	1.70	1.3	1	1	1	11.3		332	0.0125
3	117	351	0	351	24	1.70	1.3	1	1	1	54.4		541	0.0077
5	117	585	0	585	3	1.70	1.3	1	1	1	6.8	Fill	420	0.0099
7	117	819	125	694	2	1.70	1.3	1	1	1	4.5		420	0.0099
9	117	1053	250	803	9	1.62	1.3	1	1	1	19.5		566	0.0074
11	117	1287	374	913	5	1.52	1.3	1	1	1	10.2	SP	527	0.0079
13	117	1521	499	1022	13	1.44	1.3	1	1	1	24.9	ML	635	0.0066
15	117	1755	624	1131	N/A	1.37	1.3	1	1	1	N/A	CL	N/A	N/A
17	117	1989	749	1240	48	1.31	1.3	1	1	1	83.6	ML	823	0.0051
19	117	2223	874	1349	14	1.25	1.3	1	1	1	23.4		677	0.0062
21	117	2457	998	1459	16	1.20	1.3	1	1	1	25.7	CL	702	0.0059
23	117	2691	1123	1568	28	1.16	1.3	1	1	1	43.4		782	0.0053
25	117	2925	1248	1677	30	1.12	1.3	1	1	1	44.9		800	0.0052

APPENDIX-B

GeoSonics Internet Protocol Seismic Remote Specifications

GeoSonics Internet Protocol Seismic Remote Specifications

Ip2 and IpWR Remote Blast Monitoring Seismographs

Velocity measurements-

Resolution: 0.0025 in/sec. (0.06 mm/sec.).
Range: 0.003 to 5.120 in/sec. (130 mm/sec.), (other ranges available)
Frequency Response: 2 to 250 Hz (3 dB) / 2 to 1,000 Hz (Nyquist).
Sampling Rate: 1, 2 or 3 milliseconds.

Accuracy: 5% within one year (multi-frequency calibrated).*
Calibration: Internal dynamic.

Air over-pressure measurements-

Resolution: 0.0000178 psi
Range: 78dB – 142dB, (other ranges available)
Frequency Range (3 dB): 2 to 250 Hz (3 dB) / 2 to 1,000 Hz (Nyquist).

Accuracy: 10% (1dB) within one year (multi-frequency calibrated).*
Calibration: Internal electronic.

Sound Trigger: Range (Linear): 81 to 142 dB. / Off

Vibration Trigger: Selectable- 0.005 to 5.120 Ips / Off

System Time: System time is GMT (UTC) with provisions for storing preferred time zone, (typically, local recording time) for report generation.

Operational Modes: Continuous Monitor (Histogram), Triggered mode (waveform recording) and Dual Mode

Continuous (Histogram):

- Vibration Data: Peak particle velocity and frequency for L, T & V
- Sound Data (Linear): 78 to 142 dB.
- Recording Intervals: Selectable: 1 to 60 seconds

Time History Recordings- (Triggered mode operation): When data is collected as time history recordings, the unit continually scans at the appropriate sampling rate (0.5,1,2 or 3 milliseconds) and holds the most current 500 samples for pre-trigger data. On trigger exeedance, pre-trigger data is written to the record and data collection continues until selected record time has elapsed (including pre-trigger).

- 1 to 2.5 sec. - 500 microsecond sampling (2000sps)
- 2.6 to 5 sec. - 1 millisecond sampling (1000sps)
- 6 to 10 sec. - 2 millisecond sampling (500sps)
- 11 to 15 sec. - 3 millisecond sampling (333sps)

Multiple part time history records: Consecutive waveform recordings up to 2-1/2 minutes.

Dual Mode:

- When initiated in Dual-mode - unit begins to record an interval peak histogram (without freq.) according to instrument setup
- On trigger exceedance, unit closes histogram, records a time-history, according to setup, on completion, unit initiates a new histogram.
- Pre-trigger data of waveform contains last 500 samples of preceding histogram.

Data Storage Capacity: Ip Interface Controller archives all recordings for up to 2 years or until remotely managed or manually cleared.

* GeoSonics Blast Monitoring Seismographs are manufactured, tested and calibrated to insure compliance with the ISEE recommended Performance Specifications for Blasting Seismographs, 2011 Edition.

GeoSonics

GeoSonics.com
P.O Box 506
Warrendale, PA 15086
Phone 724.934.2900
Fax 724.934.2999

Appendix B

Exceedance Documentation Report

Exceedance Documentation Report

Prepared by:______________
Date:______________

General Description of Exceedance:____

Location and Monitor Involved in Exceedance:____

Note location of all data collected during the exceedance: ________________________________

Type of Exceedance: Alert Level ☐ Action Level ☐

Was a change in Site Condition initiated: Yes ☐ No ☐ Describe:______________________________

Description of Site Remediation Activities:____
____

Possible Non-Remediation Activities Causing Vibrations:_____________________________________
____

Describe exceedance including discovery, potential cause, and response taken.
(Continue on back if necessary)

____
____
____
____

Date and time incident discovered____

Date and time incident occurred:____

Name of person who discovered incident:____

Was follow-up monitoring conducted?____
(Attach results of additional monitoring to form)

Were any complaints received from the public?____
(Indicate who and what actions taken)

List individuals that were notified of the incident:______________________________________
____

What action steps are taken (or planned) to prevent any recurrence of similar incident:

____
____
____
____