APPENDIX 28-1. BLASTING MONITORING PROGRAM

AGNICO EAGLE

MELIADINE GOLD MINE

Blast Monitoring Program

MARCH 2024
VERSION 6

ᓇᐃᓈᖅᓯᒪᔪᖅ

ᐊᒡᓃᑯ ᐄᒍ ᐅᔾᕿᒃᑕᕆᐊᓕᕆᔨᒃᑯᑦ - ᐊᐳᖅᑎᓈᖅᑐᒥᑦ (ᐊᒡᓃᑯᒃᑯᑦ) ᓇᖕᒥᓂᖃᖅᑐᑦ ᐊᒻᒪᓗ ᐊᐅᓛᖅᑎᕐᓗᒍ ᑕᓯᕐᔪᐊᕐᒥᑦ ᒎᓗᒧᑦ ᐅᔾᕿᒃᑕᕆᐊᖅ (ᐅᔾᕿᒃᑕᕆᐊᖅ) 25 ᑭᓛᒥᑕᓪᓗᐊᓂᒃ ᐅᖓᓯᒃᑎᒋᔪᖅ ᐅᐊᖕᓇᖕᓂᑦ ᑲᖏᖅᖠᓂᕐᒥᑦ, ᐊᒻᒪᓗ 80 ᑭᓛᒥᑕᓂᒃ ᐅᖓᓯᒃᑎᒋᑉᓗᓂ ᓂᒋᖅᐸᓯᐊᓂᑦ ᐱᖓᖕᓇᖅᐸᓯᐊᓂᑦ ᐃᒡᓗᓕᒑᕐᒧᔪᖕᒥᑦ ᑭᕙᓪᓕᕐᒥᑦ ᓄᓇᕗᒻᒥᑦ. ᐅᔾᕿᒃᑕᕆᐊᕐᒧᑦ ᐸᕐᓇᐅᑎᒥᑦ ᐃᓚᐅᔪᑦ ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᖅ ᐊᒻᒪᓗ ᓄᓇᐅᑉ ᐃᓗᐊᓂᑦ ᐅᔾᕿᒃᑕᕆᐊᑦ ᐱᕙᓪᓕᐊᔾᔨᐅᓂᖓᓄᑦ ᑎᕆᒐᓂᐊᖅ ᒎᓗᑕᓕᒃ, ᒪᕐᑮᖕᓂᒃ ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᖃᕐᓗᓂ (ᑎᕆᒐᓂᐊᖅ ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᖅ 1 ᐊᒻᒪᓗ ᑎᕆᒐᓂᐊᖅ ᓄᓇᒥᑦ ᐅᒃᑯᐃᖓᔪᖅ 2) ᐊᒻᒪᓗ ᐊᑕᐅᓯᖅ ᓄᓇᐅᑉ ᐃᓗᐊᓂᑦ ᐅᔾᕿᒃᑕᕆᐊᖅ. ᐅᔾᕿᒃᑕᕆᐊᖅ ᐱᓕᐅᕆᕙᓪᓕᐊᓕᓚᐅᖅᑐᖅ Q1-2019. ᐊᒥᓱᑦ ᐸᕐᓇᐅᑕᐅᓯᒪᔪᑦ ᐊᒻᒪᓗ ᓄᓇᐅᑉ ᖃᖓᓂᑦ ᓴᓇᔾᔭᐅᕙᓪᓕᐊᔪᑦ ᐊᑐᕆᐊᖃᖅᑐᑦ ᖃᖅᑕᖅᑐᓂᒃ ᐃᓚᒋᔾᔭᐅᑉᓗᓂ ᐅᔾᕿᒃᑕᖅᑕᐅᔪᓕᕆᓂᐅᔪᓄᑦ.

ᑎᑎᖅᑲᖅ ᐱᔾᔪᑎᖃᖅᑐᖅ ᖄᖅᑎᕆᓂᕐᒥᒃ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᑐᕌᖓᔪᒥᒃ (ᑐᕌᖓᔪᖅ) ᐅᔾᕿᒃᑕᕆᐊᕐᒧᑦ, ᒪᓕᒃᑲᓂ ᐱᓕᕆᐊᕐᒧᑦ ᓇᓗᓇᐃᒃᑯᑕᖅ ᓈᓴᐅᑎ 006-ᒥᑦ ᑐᓂᔭᐅᔪᖅ ᐊᕙᑎᓕᕆᔨᒃᑯᓐᓄᑦ. ᑐᕌᖓᔪᖅ ᑐᓪᓕᖓ ᐋᖅᑭᒋᐊᖅᑕᐅᓯᒪᔪᖅ ᑎᑎᖅᑲᒦᑦᑐᖅ ᐅᖃᐅᓯᖃᖅᑐᖅ ᐊᒡᓃᑯ ᐄᒍ ᐅᔾᕿᒃᑕᕆᐊᓕᕆᔨᒃᑯᑦ (ᐊᒡᓃᑯᒃᑯᑦ) ᖃᓄᖅᑑᕈᑎᒌᓐᓇᖅᑕᖕᓂᒃ ᖄᖅᑎᕆᓂᕐᒥᑦ ᓴᔪᕿᓛᒃᑐᓂᒃ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᐃᓚᐅᔪᑦ ᓄᓇᐅᑉ ᖄᖓᓂᑦ, ᓄᓇᐅᑉ ᐃᓗᐊᓂᑦ ᐊᒻᒪᓗ ᓴᓇᔾᔭᐅᕙᓪᓕᐊᔪᓂᑦ ᖄᖅᑎᕆᓂᕐᓂᒃ ᑕᓯᕐᔪᐊᕐᒥᑦ ᒎᓗᒧᑦ ᐅᔾᕿᒃᑕᕆᐊᕐᒥᑦ (ᐅᔾᕿᒃᑕᕆᐊᖅ).

ᒪᓕᒃᑕᐅᔪᒃᓴᐃᑦ ᐊᑐᖅᑕᐅᓂᖏᓐᓄᑦ ᖄᖅᑕᖅᑐᐃᑦ ᑕᐃᑲᓂ ᐅᕝᕙᓘᓐᓃᑦ ᖃᓂᑕᖏᓐᓂᑦ ᑲᓇᑕᐅᑉ ᐃᒪᖏᓐᓂᑦ (Wright and Hopky, 1998) ᐋᖅᑭᐊᖅᑕᐅᓂᖓᑐᑦ ᐃᖃᓗᓕᕆᔨᒃᑯᓐᓄᑦ ᐊᑐᕐᓂᐊᕐᓗᓂ ᐅᑭᐅᖅᑕᖅᑐᒥᑦ ᐅᖃᖅᓯᒪᔪᑦ ᐅᑯᐊ ᐱᔭᕆᐊᖃᖅᑐᑦ ᐅᔾᕿᒃᑕᕆᐊᕐᒧᑦ:

- ᖄᖅᑕᖅᑐᒥᑦ ᖄᖅᑎᕆᓂᖅᑕᖃᕐᓂᐊᖏᓚᖅ ᑕᐃᑲᓂ ᐅᕝᕙᓘᓐᓃᑦ ᖃᓂᑕᖏᓐᓂᑦ ᐃᒡᓕᖏᓐᓂᑦ, ᐅᕝᕙᓘᓐᓃᑦ ᐃᒡᓕᓕᐅᕐᕕᐅᑐᐃᓐᓇᓇᐊᓕᖕᒥᑦ, ᑕᒡᕙᑦᑕᐃᓐᓇᖅ ᐃᒪᐅᑉ ᓴᙱᓂᖓ ᐊᓯᐊᙳᕐᓗᓂ (ᓲᕐᓗ ᐅᖓᑎᖓᓄᑦ ᓴᙱᓂᖅ) ᐊᖏᓂᖅᓴᐅᔪᒥᑦ 100 kPa-ᓂᒃ ᐃᖃᓘᑉ ᐳᕕᖃᑦᑕᖅᑐᖓᓂᑦ.
- ᖄᖅᑕᖅᑐᒥᑦ ᖄᖅᑎᕆᓂᖅᑕᖃᕐᓂᐊᖏᓚᖅ ᐊᖏᓂᖅᓴᐅᔪᒥᒃ 13 ᒥᓕᒦᑕᓂᒃ ᖃᐅᔨᓴᐅᑎᐅᑉ ᑎᒡᓕᒃᑖᖓᓂᑦ ᐊᖏᓂᖅᓴᐅᔪᒥᒃ ᐃᒡᓕᓂᑦ ᐃᖃᓗᐃᑦ ᒫᓂᖃᖅᑎᓪᓗᒋᑦ.

ᖃᐅᔨᓴᐃᓂᖃᖅᑳᖅᑎᓪᓗᒋᑦ ᐊᒻᒪᓗ ᖃᓄᐃᖓᓂᐅᔪᓂᒃ ᓄᓇᑦᑎᐊᕐᒥᑦ ᓇᓗᓇᐃᖅᓯᔪᑦ ᑭᒡᓕᐅᔪᖅ 100 kPa-ᓂᒃ ᓈᒻᒪᓚᐅᖕᒋᑦᑐᖅ ᒥᐊᓂᕆᓂᐊᕐᓗᒋᑦ ᐃᖃᓗᐃᑦ ᐃᓂᖕᒋᑦ, ᐃᖃᓗᓕᕆᔨᒃᑯᑦ ᐋᖅᑭᐊᖅᓯᓚᐅᖅᑐᑦ ᐊᒻᒪᓗ ᐃᒪᓈᖅᑐᐃᑉᓗᑎᒃ ᐊᒡᓃᑯᒃᑯᑦ ᒪᓕᖕᓂᐊᖅᑕᖕᒋᓐᓂᒃ ᐋᖅᑭᐊᖅᓯᒪᔪᒥᒃ 50 kPa-ᒧᑦ ᑕᒡᕙᑦᑕᐃᓐᓇᖅ ᓴᙱᓂᐅᔪᖅ ᐊᓯᐊᙳᕐᓂᕐᒧᑦ.

ᖃᐅᔨᓴᓂᑦ ᖃᐅᔨᓴᖅᑕᐅᒃᑲᑦᑕᖅᑐᑦ ᖃᐅᔨᓴᐃᓂᕐᒧᑦ ᐊᑐᖅᑕᐅᒃᑲᑦᑕᖅᑐᒧᑦ, ᑕᐃᒪᓐᓇᐃᑦᑐᓕᕆᔾᔪᑎᒧᓪᓘᓐᓃᑦ, ᓴᔪᕿᓛᖅᑐᑦ ᖃᐅᔨᓴᕐᓂᕐᒥᑦ ᐱᔪᑦ ᑐᖔᓐᓂᓐᓂᐊᕐᓗᓂ 13 ᒥᓕᒦᑕᓂᒃ ᖃᐅᔨᓴᐅᑎᐅᑉ ᑎᒡᓕᒃᑖᖓᓂᑦ ᐊᒻᒪᓗ ᐅᖓᑎᖓᓄᑦ ᓴᙱᓂᖅ ᑐᖔᓂᓪᓗᓂ 50 kPa-ᒥᑦ. ᖃᐅᔨᓴᓂᑦ ᖃᐅᔨᓴᖅᑕᐅᒃᑲᑦᑕᖅᑐᑦ ᐱᖓᓱᑦ ᐃᓂᐅᔪᓄᑦ ᑎᑭᓪᓗᒍ ᐅᔾᕿᒃᑕᕆᐊᕐᒥᑦ; ᓄᓇᐅᑉ ᖃᖓᓂᑦ ᖃᐅᔨᓴᓂᖃᑕᐅᒃᑲᑦᑕᖅᑐᑦ ᐊᒃᑐᖅᓯᓂᕐᒧᑦ ᖃᐅᔨᑎᑦᑎᓂᐊᖅᑐᖅ ᓴᓇᔾᔭᐅᓗᑎᒃ ᒪᕐᑮᒃ ᓄᑖᒃ ᖃᐅᔨᓴᐃᕝᕕᙱᓄᑦ ᐃᓂᐅᔪᓂ. ᓱᓇᑐᐃᓐᓇᓕᐅᕆᔨᒃᑯᑦ 24 ᐃᑲᕐᕋᓂᑦ ᖃᐅᔨᓴᖅᑳᖅᑎᓪᓗᒋᑦ

ᖃᐅᔨᓴᐃᖃᑦᑕᕐᓂᐊᖅᑐᑦ ᖃᓄᐃᖓᓂᐅᔪᓂᒃ ᖄᖅᑎᕆᓂᕐᒧᑦ ᖃᐅᔨᓴᐃᓂᓗᒃᑖᓂᑦ. ᑐᑭᓕᐅᖅᑕᐅᓯᒪᔪᑦ ᖃᓄᐃᖓᓂᐅᔪᑦ ᐅᖓᑕᐅᑦᑎᒃᐸᑕ ᒪᓕᒐᕋᓛᓂᒃ, ᖄᖅᑎᕆᓂᕐᒧᑦ ᐊᖏᓗᐊᖏᒋᐊᖅᑎᑦᑎᓂᕐᒥᒃ ᐸᕐᓇᐅᑎᒥᒃ ᐊᑐᓕᖅᑎᑦᑎᑲᐅᑎᒋᓇᔭᖅᑐᑦ; ᒫᓐᓇᒧᑦ ᑎᑭᖦᖢᒍ, ᐊᑕᐅᓯᖅ ᖄᖅᑎᕆᓂᖅ 2019 ᐱᒋᐊᓵᖅᑎᓪᓗᒍ ᐅᖓᑕᐅᑦᑎᓚᐅᖅᑐᖅ ᑭᓪᓕᐅᔪᓂᒃ ᑕᓯᕐᔪᐊᕐᒥᑦ.

EXECUTIVE SUMMARY

Agnico Eagle Mines Limited – Meliadine Division (Agnico Eagle) is operating the Meliadine Gold Mine (Mine), located approximately 25 kilometres (km) north of Rankin Inlet, and 80 km southwest of Chesterfield Inlet in the Kivalliq Region of Nunavut. The mine plan includes open pit and underground mining methods for the development of the Tiriganiaq gold deposit, with two open pits (Tiriganiaq Pit 1 and Tiriganiaq Pit 2; TIR01 and TIR02) and one underground mine. The Mine entered commercial production in Q2, 2019. Many planned and ongoing surface construction projects require the use of explosives in addition to the mineral development process.

This document presents the Blast Monitoring Program (the Program) for the Mine, describing Agnico Eagle's continued strategy regarding Blast Vibration Monitoring including surface, underground and construction blasting for the Mine.

The Guidelines for the use of Explosives in or Near Canadian Waters (Wright and Hopky, 1998) as modified by the Department of Fisheries and Oceans Canada (DFO) for use in the North mention the following requirements that are applicable to the Mine:

- No explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (i.e. overpressure) greater than 100 kPa in the swim bladder of a fish.
- No explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/sec in a spawning bed during the period of egg incubation.

Following testing and monitoring results in the Northwest Territories (NWT) indicating the limit of 100 kPa was insufficient for the protection of the fish habitat, DFO amended and recommend that Agnico Eagle comply with a revised 50 kPa threshold for instantaneous pressure change.

Blasts are monitored with Instantel Blast monitoring equipment, to ensure that vibrations generated by blasting are less than 13 mm/sec and the overpressure is under 50 kPa. The blasts are monitored from up to three permanent locations on the Mine property.

The Engineering department within the 24 hours following the blasting operation systematically analyze the results of all blast monitoring. Should the interpreted results exceed regulations, a blast mitigation plan would be immediately implemented.

TABLE OF CONTENTS

DOCUMENT CONTROL

Version	Date	Section	Page	Revision	Author
1	March 2017			First version of the Blast Monitoring Program	Vanessa Smith, Mine Engineer
2	March 2020			Revision due to start of underground production stope blasting and open pit operations	Vanessa Smith, Project Coordinator
3	March 2021			Update of the monitoring location and removal of the previous year results (now appendix of the Annual report)	Jawad Haloui, Engineering Superintendent
4	April 2022			General Update	Jean-Francois Horth, Engineering Coordinator
5	March 2023			General Update	Jean-Francois Horth, Engineering Coordinator
6	March 2024			General Update Revised Table 3, Section 3.1, Table 5, Section 6	Meliadine Engineering Department

IMPLEMENTATION SCHEDULE

This Plan has been in effect since April 2017.

DISTRIBUTION LIST

Agnico Eagle – Environment Superintendent
Agnico Eagle – Environment Coordinators
Agnico Eagle – Engineering Superintendent
Agnico Eagle – Engineering Coordinators

ACRONYMS

Agnico Eagle	Agnico Eagle Mines Limited
ANN	Artificial Neural Network
BGAM	Boosted Generalised Additive Model
DFO	Department of Fisheries and Oceans Canada
GN	Government of Nunavut
IOL	Inuit Owned Lands
Mine	Meliadine Gold Mine
NIOSH	Institute of National Occupational Safety and Health
NIRB	Nunavut Impact Review Board
NWT	Northwest Territories
PAO	Peak Air Overpressure
PPV	Peak Particle Velocity
PSP	Peak Sound Pressure
PVS	Peak Vector Sum
SD	Scaled Distance
SVM	Support Vector Machine
USBM	United States Bureau of Mines
USGS	United States Geological Survey
VEC	Valued Ecosystem Component

UNITS

km	kilometre
m	metre
t	metric tonnes
Min/sec	Minutes per second
kPa	Kilopascals

SECTION 1 • INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) is operating the Meliadine Gold Mine (Mine), located approximately 25 kilometres (km) north of Rankin Inlet, and 80 km southwest of Chesterfield Inlet in the Kivalliq Region of Nunavut. Situated on the western shore of Hudson Bay, the Project site is located on a peninsula between the east, south, and west basins of Meliadine Lake (63°1’23.8’’ N, 92°13’6.42"W), on Inuit Owned Lands (IOL). The Mine is located within the Meliadine Lake watershed of the Wilson Water Management Area (Nunavut Water Regulations Schedule 4).

This document presents the Blast Monitoring Program (the Program) for the Mine. The Program is the sixth revision of this document describing Agnico Eagle’s continued strategy regarding Blast Vibration Monitoring including surface, underground and construction blasting for the Mine.

Agnico Eagle developed the Program to minimize the effects of blasting on fish and fish habitat, water quality, and wildlife and terrestrial Valued Ecosystem Components (VECs). The Program considers Department of Fisheries and Oceans (DFO) and the Government of Nunavut (GN) regulations including:

1. Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky, 1998) as modified by the DFO for use in the North;
2. Guidance provided in the Monitoring Explosive-Based Winter Seismic Exploration in Waterbodies, NWT 2000-2002 (Cott and Hanna, 2005);
3. Include a monitoring and mitigation plan to be developed in consultation with the DFO, and obtain DFO approval of the blasting program prior to the commencement of blasting;
4. Restrict blasting when migrating caribou, or sensitive local carnivores or birds may be negatively affected; and
5. Minimize the use of ammonium nitrate to reduce the effects of blasting on receiving water quality.

The Program is in effect since 2017; the Program will continue to be in effect and revised when conditions warrant doing so.

SECTION 2 • BLASTING STANDARDS AND CRITERIA

Although blasting is one of the most widely used methods for rock fragmentation, it has a major disadvantage in that it causes adjacent ground vibrations. Prediction of blast-induced ground vibration is essential for evaluating and controlling adverse consequences of surface blasting including potential harm to nearby fish and fish habitat, water quality, wildlife and terrestrial VECs.

Peak particle velocity (PPV) is a measure used for ground vibrations; however, accurate prediction of PPV is challenging for blasters and management alike. A study conducted by Nguyen et al (2019) compared the results of three PPV determination tools with respect to prediction accuracy: boosted generalised additive models (BGAMs), support vector machine (SVM) and artificial neural network (ANN). Results revealed that the elevation difference between the blasting site and monitoring point is one of the predominant parameters governing the PPV predictive models. It is not currently in the mandate of the drill and blast team to predict the PPV value for any blasts but rather monitor and trend collected data. As the mine progresses and larger surface blasts are planned, prediction could be a proactive means to avoid exceeding regulatory limits.

Singh and Vogt (1998) stated that the charge weight could affect the ground vibration only at distances close to the blasts with the effects that diminish quickly with distance. Persson (1994) stated that the magnitude of ground vibrations depended on the quantity of explosives, characteristics of the rock, distance from the blasting site and geology of the deposits.

US Geological Survey (USGS) or National Institute for Occupational Safety and Health (NIOSH), formerly the United States Bureau of Mines (USBM) proposes an empirical vibration predictor equation to calculate the PPV produced by a blast reliant on two factors, namely maximum charge per delay and distance from the blast face. In the USGS model, a scaled distance (SD) factor was calculated based on the following equation:

$$SD = (D/\sqrt{MC}),$$

Where *D* and MC are distance (m) and maximum charge per delay (kg). Accordingly, the PPV is calculated using the following equation:

$$PPV=K\ (SD)^{B}$$

Where *B* and *K* are site constants and PPV is peak particle velocity (mm/s).

Such empirical approaches do not account for other controllable or non-controllable parameters such as burden, spacing, stemming and powder factor and their effect on the PPV.

2.1 Effects on Fish

The detonation of explosives in or near water produces post-detonation compressive shock waves characterized by a rapid rise to a high peak pressure followed by a rapid decay to below ambient hydrostatic pressure. The latter pressure deficit causes most impacts on fish.

The primary site of damage in finfish is the swim bladder, the gas-filled organ that permits most pelagic fish to maintain neutral buoyancy. The kidney, liver, spleen, and sinus venous also may rupture and haemorrhage. Fish eggs and larvae also may be killed or damaged (Wright 1982).

Studies (Wright 1982) show that an overpressure in excess of 100 kPa will result in these effects. The degree of damage is related to type of explosive, size and pattern of the charge(s), method of detonation, distance from the point of detonation, water depth, and species, size and life stage of fish.

Vibrations from the detonation of explosives may cause damage to incubating eggs (Wright 1982, Wright in prep.). Sublethal effects, such as changes in behaviour of fish, have been observed on several occasions as a result of noise produced by explosives. The effects may be intensified in the presence of ice and in areas of hard substrate (Wright 1982, Wright in prep.).

The detonation of explosives may be lethal to marine mammals and may cause auditory damage under certain conditions. The detonation of explosives in the proximity of marine mammals also has been demonstrated to induce changes in behaviour (Wright in prep.).

The number of shellfish and crustaceans killed by the detonation of explosives is believed to be negligible, however, little data is available. Sublethal effects of explosives on shellfish and crustaceans including behavioural modifications are little known or understood (Wright 1982, Wright in prep.).

2.2 Effects on Fish Habitat

The use of explosives in and near fish habitat may also result in the physical and/or chemical alteration of that habitat. For example, sedimentation resulting from the use of explosives may cover spawning areas or may reduce or eliminate bottom-dwelling life forms that fish use for food. By-products from the detonation of explosives may include ammonia or similar compounds and may be toxic to fish and other aquatic biota (Wright in prep.).

2.3 DFO Amended Threshold

Fish and fish habitat can be damaged through vibrations, shock waves, and physical changes caused by blasting. DFO has established guidelines for determining setback distances for eliminating blasting effects on fish due to pressure (acoustic) effects as well as peak particle velocity; these guidelines include:

- No explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (i.e., overpressure) greater than 100 kPa (14.5 psi) in the swim bladder of a fish.

- No explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm•s-1 in a spawning bed during the period of egg incubation.

Following testing and monitoring results in the NWT, the limit of 100 kPa was determined to be insufficient for the protection of the fish habitat, DFO amended and recommend that Agnico Eagle comply with a revised 50 kPa threshold for instantaneous pressure change.

To keep PPV under the 13 mm/sec guideline, Wright and Hopky (1998) suggest the setback distances (m) from the centre of detonation of a confined explosive to spawning habitat to achieve 13 mm/sec guideline criteria for all types of substrate shown in Table 1.

Table 1. Setback distance (m) from centre of detonation of a confined explosive to spawning habitat to achieve 13 mm•sec-1 guideline criteria for all types of substrate.

WEIGHT OF EXPLOSIVE CHARGE (KG)	0.5	1	5	10	25	50	100
SETBACK DISTANCE (m)	10.7	15.1	33.7	47.8	75.5	106.7	150.9

Concerning the instantaneous pressure change (i.e. overpressure); Wright and Hopky (1998) suggest the following setback distances to keep it under the 100 kPa guideline (Table 2).

Table 2. Set back distance (m) from center of detonation of a confined explosive to fish habitat to achieve 100 KPa guideline criteria for various substrate.

Substrate Type	Weight of Explosive Charge (kg)							
	0.5	1	2	5	10	25	50	100
Rock	3.6	5.0	7.1	11.0	15.9	25.0	35.6	50.3
Frozen Soil	3.3	4.7	6.5	10.4	14.7	23.2	32.9	46.5
Ice	3.0	4.2	5.9	9.3	3.2	20.9	29.5	41.8
Saturated Soil	3.0	4.2	5.9	9.3	13.2	20.9	29.5	41.8
Unsaturated Soil	2.0	2.9	4.1	6.5	9.2	14.5	20.5	29.0

The Meliadine Engineering team currently has historical surface data for Containment Pond 4 (CP4), Saline Pond 2 (SP2), Saline Pond 4 (SP4), Containment Pond 6 (CP6), TIR01 and TIR02 blasting. This data is available in the event special blasting circumstances need to be addressed.

SECTION 3 • INSTRUMENTATION

Every blast is monitored to ensure that vibrations generated by blasting are less than 13 mm/sec and the overpressure is under 50 KPa. The instrument used for blast monitoring is an Instantel Minimate Blaster, or equivalent, which is fully compliant with the international Society of Explosives and Engineers performance specification for blasting seismographs (Instantel, 2005). The instruments used in Meliadine are calibrated regularly following the manufacturer's recommendations and are presented in Table 3.

Table 3. Meliadine Mine Blast Monitoring Hardware

MODEL	LOCATION	SERIAL	TRIGGER LEVEL
Minimate Pro 4	HW 125 (Underground)	MP13824	Geo 1.00 mm/s
Minimate Pro 4	ESS-175W (Underground) (Decommissioned Q4 2023)	MP14516	Geo 1.00 mm/s
Minimate Pro 4	ESS-275 (Underground)	MP14515	Geo 1.00 mm/s
Minimate Pro 4	ESS-375 (Underground)	MP14381	Geo 1.00 mm/s
Minimate Pro 4	ESS-400 (Underground)	MP14517	Geo 1.00 mm/s
Minimate Pro 4	RP3-425-400 (Underground)	MP14380	Geo 1.00 mm/s
Minimate Pro 4	Communication Tower P1 (Surface)	MP14207	Geo 1.00 mm/s
Minimate Pro 4	Exploration Camp (Surface)	MP14208	Geo 1.00 mm/s

The Minimate Blaster has three main parts: a monitor, a standard transducer (geophone) and a microphone (Figure 1). The monitor contains the battery and electronic components of the instrument. It also checks the two sensors to be sure that they work properly. The transducer measures ground vibration with a mechanism called a geophone.

Figure 1. Minimate Pro4 components

The transducer has three geophones that measure the ground vibrations in terms of particle velocity. They measure transverse, vertical and longitudinal ground vibrations (Figure 2). Transverse ground vibrations agitate particles in a side-to-side motion. Vertical ground vibrations agitate particles in an up and down motion. Longitudinal ground vibrations agitate particles in a back and forth motion progressing outward from the event site (Instantel, 2016).

The microphone measures the PSP (Peak Sound Pressure) also referred as to the PAO (Peak Air Overpressure). The instrument checks the entire event waveform and displays the largest sound pressure in Pa unit.

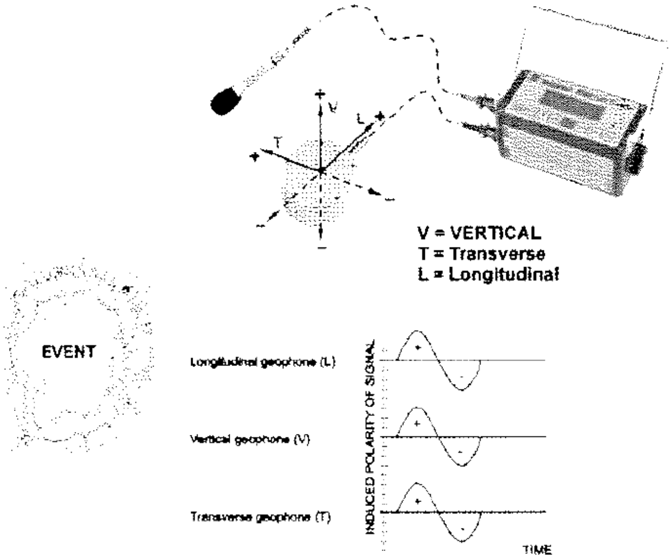


Figure 2. Sensor Orientation (Instantel, 2005)

The Minimate Blaster (Instantel) calculates the PPV for each geophone and calculates the vector sum of the three axes.

The result is the PVS (Peak Vector Sum) and it is the resultant particle velocity magnitude of the event:

$$PVS = \sqrt{(T^2 + V^2 + L^2)}$$

Where:

T = particle velocity along the transverse plane

V = particle velocity along the vertical plane

L = particle velocity along the longitudinal plane

3.1 Instrument Underground Installation

In 2023, six permanent seismographs were present underground, as shown in Table 3. The trigger level of the instrument is set to 1 mm/s and the transducer starts recording an event automatically when the ground vibrations are greater than or equal to 1 mm/s. The recording time is 20 seconds and underground blasts typically last 15 seconds. As production increases, this window may have to be increased as the underground blast timing increases. The installations do not require additional protection as they are distanced sufficiently from underground traffic.

Figure 3. Previous Underground Installation (L75) shown as an example – (*Date:2019*)

3.2 Instrument Surface Installations

To improve vibration monitoring practices and data accuracy, permanent monitoring installations were commissioned in 2020 which allow the seismograph to be directly anchored into the bedrock via attachment to a steel rod drilled through the tundra. These permanent stations thereafter replaced the temporary locations used earlier in the year 2020 and throughout 2019. The locations were chosen to have the optimal distance between the blasts and the water (fish habitat) and are presented in Table 4 and in Figure 4 to Figure 6.

Table 4. Surface blast monitoring station coordinates

LOCATION	EASTING	NORTHING	Description
Exploration Camp	541927.162	6989073.053	Permanent location used for TIR01 & TIR02 (installed 2020-08-20)
Communication Tower P1	539803.785	6988836.212	Permanent location used for TIR01 & TIR02 (installed 2020-08-20)

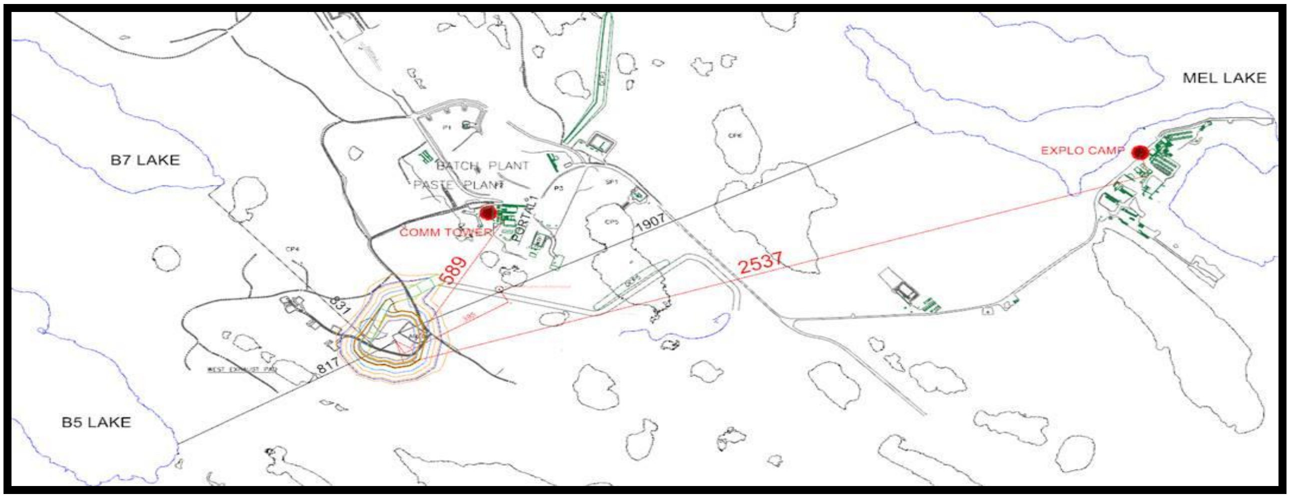


Figure 4. Surface blast monitoring station locations for TIR01 blasts (distances in meters)

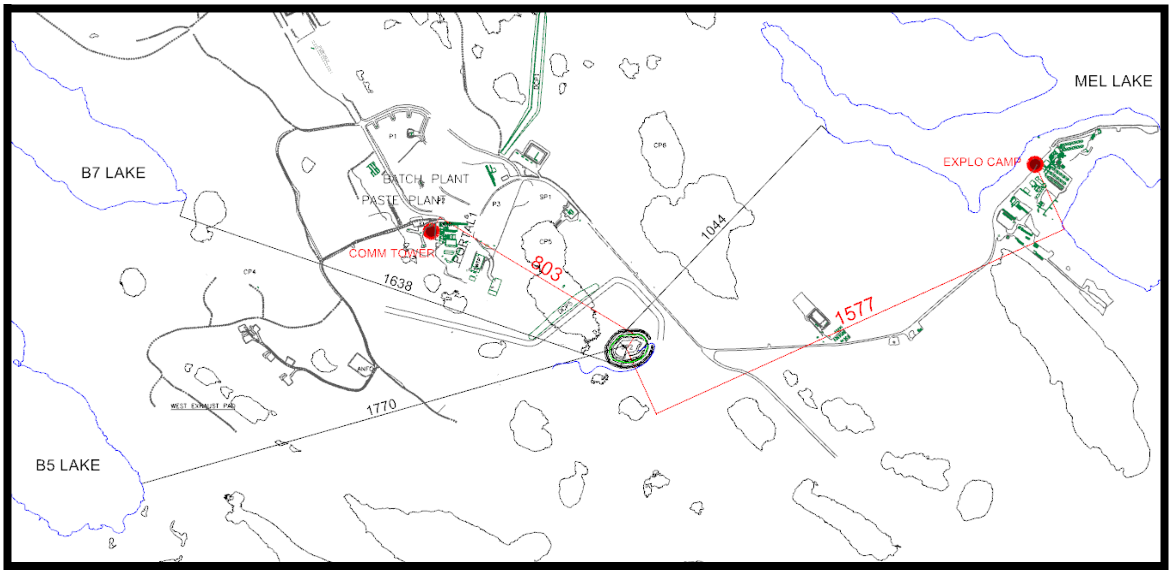
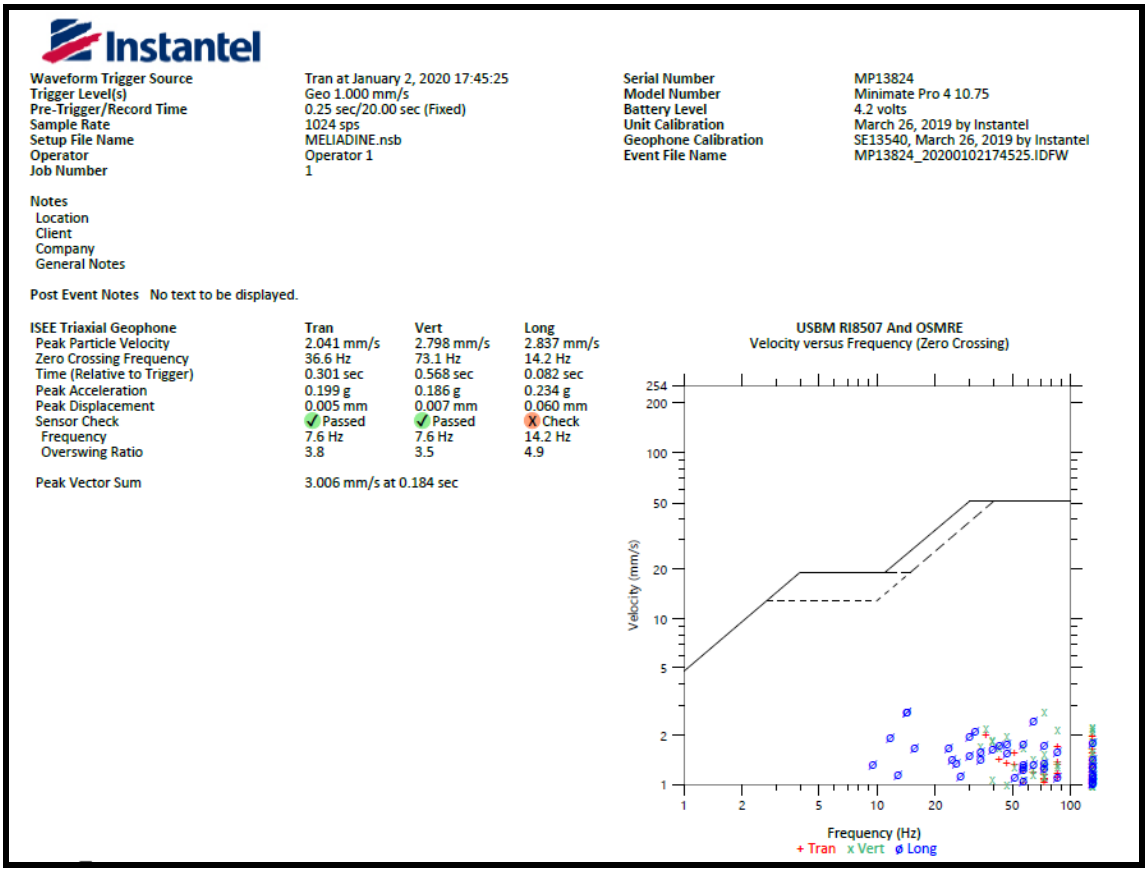


Figure 5. Surface blast monitoring station locations for TIR02 blasts (distances in meters)

Figure 6. Surface Installation (Shelter & installation inside)

3.3 Instrumentation Reports

After each blast, the results are stored in a database and the report saved in the library for future reference. The blast monitoring results are interpreted, and a blast mitigation plan is implemented immediately if the vibrations or the overpressure exceed the permitted limit (see section 4). Figure 7 is an example of an Instantel Sample Vibration Report.



Waveform Trigger Source	Tran at January 2, 2020 17:45:25	**Serial Number**	MP13824
Trigger Level(s)	Geo 1.000 mm/s	**Model Number**	Minimate Pro 4 10.75
Pre-Trigger/Record Time	0.25 sec/20.00 sec (Fixed)	**Battery Level**	4.2 volts
Sample Rate	1024 sps	**Unit Calibration**	March 26, 2019 by Instantel
Setup File Name	MELIADINE.nsb	**Geophone Calibration**	SE13540, March 26, 2019 by Instantel
Operator	Operator 1	**Event File Name**	MP13824_20200102174525.IDFW
Job Number	1		

Notes
Location
Client
Company
General Notes

Post Event Notes No text to be displayed.

ISEE Triaxial Geophone	Tran	Vert	Long
Peak Particle Velocity	2.041 mm/s	2.798 mm/s	2.837 mm/s
Zero Crossing Frequency	36.6 Hz	73.1 Hz	14.2 Hz
Time (Relative to Trigger)	0.301 sec	0.568 sec	0.082 sec
Peak Acceleration	0.199 g	0.186 g	0.234 g
Peak Displacement	0.005 mm	0.007 mm	0.060 mm
Sensor Check	✓ Passed	✓ Passed	☒ Check
Frequency	7.6 Hz	7.6 Hz	14.2 Hz
Overswing Ratio	3.8	3.5	4.9

Peak Vector Sum 3.006 mm/s at 0.184 sec

Figure 7. Instantel Sample Vibration Report

SECTION 4 • CONSTRUCTION BLASTING

The first surface blast monitoring campaign began in 2017; it was led by Explotech, a third-party engineering consulting service specializing in explosives and blast vibration monitoring. A full-time on-site Vibration Monitoring Program was implemented to record vibration levels experienced at an array of locations near the work. Four (4) seismographs were installed to monitor the Laydown Yard/Tank Farm blasting operations from April 2017 to June 2017 and five (5) were installed to monitor the Itivia Pit Quarry blasting operations from June 2017 to September 2017. This program was focused primarily on blast-induced damage to public and private infrastructure and minimizing the nuisance associated with blasting noise.

Since the blast monitoring program was implemented, the construction blasts were monitored for several excavations at Meliadine site and will continue to be the analysed the same way as the surface blasting.

SECTION 5 • SURFACE BLASTING

Tiriganiaq resources located close to surface are to be mined by two open pits developed above the underground mine operation: Tiriganiaq Pit 1 (Tiri01) and Tiriganiaq Pit 2 pit (Tiri02), with respective ultimate depths of 130 m and 105 m. The planned location of these pits in relation to other mine infrastructure is shown below in Figure 8.

Since the start of open pit operations during April 2020, Mining Engineers & Technicians have thoroughly documented all blasting activities from design concept to final results – which include PPV and measurements. If required, blasting procedure will be reviewed to ensure that the site remains within threshold limits and in continued compliance with regulations, as is part of the blast optimization process.

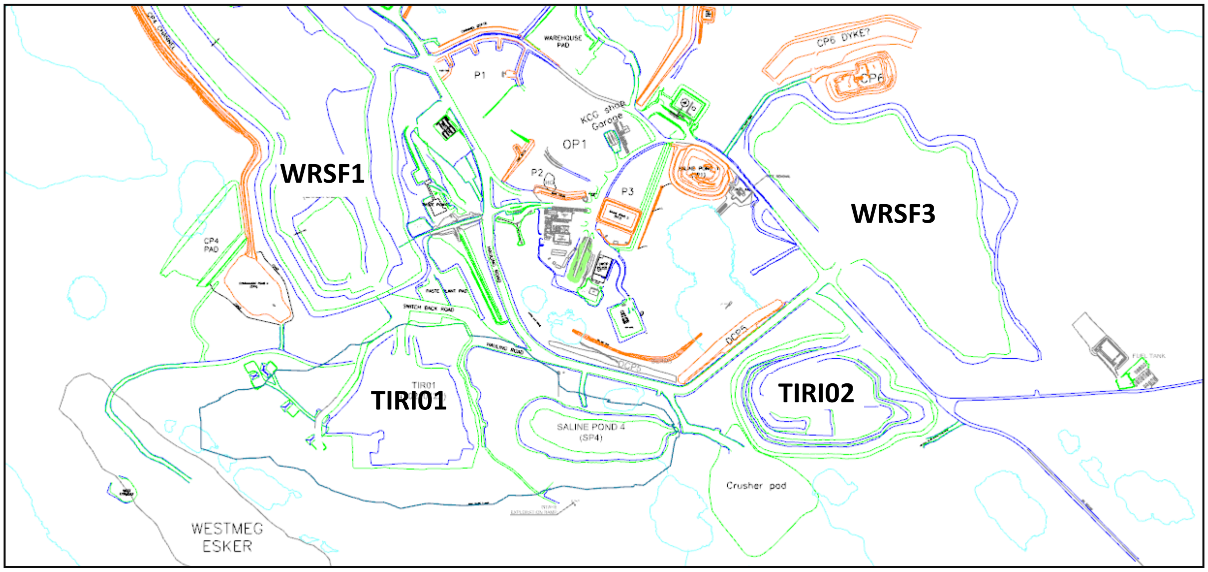


Figure 8. Open Pit Surface Plan

A conventional truck/shovel operation is used for both open pits using contractor resources for the start of the project with transitioning to Agnico Eagle resources later during the project. The same drills will be used for both production and pre-shearing.

Based on the engineering parameters, drill patterns for the selective mining zones were defined considering the material properties. The drill patterns for the non-selective mining areas are based on experiences at Meadowbank Mine, as the rock types are similar between the two mines. Moreover, these parameters will continue to be improved as mining advances. Table 5 summarizes the drilling pattern details considered for each application.

Table 5. Production Drilling Design Parameters

	Unit	Selective Mining		Non-Selective Mining	
Bench Height	m	5	10	5	10
Drill hole diameter	mm	165	165	165	165
Burden	m	4.0	4.0	4.8	4.65
Spacing	m	4.6	4.6	4.8	4.65
Sub-drill	m	0.5	1.0	1.0	1.0

It is expected that the overburden layer will be frozen and will require drilling and blasting prior to excavation. This material will have a drill pattern similar to the selective mining, as the tighter pattern performs better based on on-site construction experience.

Blasting with a high-energy bulk emulsion explosive is planned to target a powder factor from 0.32 to 0.75 kg/t in both ore and waste. Pumped emulsion reduces spillage and has excellent water resistance. This product will minimize nitrate leaching and thus reduce environmental impact (ammonia in water).

Each blast of the open pit operation will be monitored using permanent seismograph locations for real-time data collection and analysis.

SECTION 6 • UNDERGROUND BLASTING

The Mine entered commercial production in Q2-2019.

Since the start of underground stope production, 121 stope blasts exceeded 10,000 tonnes of ore blasted with only four exceeding the 30,000-tonnes triggering limit for required monitoring stated in the 2017 Program. The collected data for underground blasts confirms that these blasts will not have an effect on surface fish habitat or surface spawning beds since measured values are well below the permitted threshold of 50 kPa for overpressure and 13 millimeters per second for peak particle velocity.

SECTION 7 • BLAST MITIGATION PLAN

Should the vibrations or the overpressure approach or exceed the permitted limit, a retro analysis will be conducted to identify the factors that may have caused higher than desired results and the Environment Department will be notified. It will be important to consider the main factors influencing blast vibration intensity (Table 6, ISEE, 1998).

Table 6. Main Factors Influencing Blast Vibration Intensity & Overpressure (ISEE, 1998)

Main Factors Influencing Blast Vibration Intensity	**Main Factors Influencing Overpressure**
Maximum charge weight detonating at one time	Maximum charge weight per delay
True distance (distance the waves must travel)	Depth of burial of charges
Geological conditions	Exposed surface detonation material
Confinement	Atmospheric conditions
Physical properties of the rock	Wind
Coupling	Temperature gradients
Spatial distribution	Topography
Detonator timing scatter	Volume of displaced rock
Time of energy release	Delay interval and orientation
Type of Explosive	Type of Explosive

During open pit operations, if vibrations generated by blasting exceed the threshold of 13 mm/sec or 50 KPa overpressure, mitigation methods can be readily implemented to eliminate the effects of blasting.

Some of the mitigation methods include:

1. Reduction of charge per delay by decking the blast holes
2. Increasing the delay time between rows and holes to produce discrete explosions
3. Use of bubble/air curtains to disrupt the shock waves
4. Design of blasts and delay configurations to minimize vibrations

SECTION 7 • CONCLUSION

Environmental issues that arise from blasting increasingly restrict mining operations; for this reason, the importance of blast monitoring and trending of ground vibration are extremely important to eliminate environmental concerns. Peak Particle velocity (PPV) being the most common single ground descriptor for regulating blast designs, parameters of the common empirical relationship between peak particle velocity and scaled distance are used at Meliadine.

Blast monitoring process will continue to ensure that blast vibrations do not cause harm to aquatic life at Meliadine. Data collection started in 2017 will continue to populate the historical database providing a more varied basis to find a site-relevant confinement factor. The data collected will help correlate different factors that could influence vibration intensity; historical data will be considered in the future to guarantee a constant improvement in controlling blast vibrations.

Agnico Eagle remains committed to monitoring all blasts in order to comply with the previously mentioned requirements.

REFERENCES

International Society of Explosive Engineers (ISEE) (1998). Blasters' Handbook (17th ed.). Cleveland: International Society of Explosive Engineers.

Guidelines for the use of Explosives in or near Canadian fisheries waters. Wright, D.G., and G.E. Hopky. (1998) Can. Tech. Rep. Fish. Aquat. Sci. 2107: iv + 34p.

Instantel Minimate Pro4 Specification Sheet (2015) Xmark Corporation. Instantel, the Instantel logo, Auto Call Home, AutoRecord,Blastmate, Blastware, Histogram Combo, InstaLink, and Minimate are trademarks of Stanley Black & Decker, Inc., or its affiliates

Nguyen, H., Bui, X., Tran, Q. et al. Predicting blast-induced peak particle velocity using BGAMs, ANN and SVM: a case study at the Nui Beo open-pit coal mine in Vietnam. Environ Earth Sci 78, 479 (2019). https://doi.org/10.1007/s12665-019-8491-x

P.A. Persson, R. Holmberg, J. Lee, Rock Blasting and Explosives Engineering, CRC, USA, 1994.

P.K. Singh, W. Vogt, Ground vibration: prediction for safe and efficient blasting, Erzmetall 51 (10) (1998) 677–684.

Ozer, U., Kahriman, A., Aksoy, M. *et al.* The analysis of ground vibrations induced by bench blasting at Akyol quarry and practical blasting charts. *Environ Geol* **54,** 737–743 (2008). https://doi-org.liverpool.idm.oclc.org/10.1007/s00254-007-0859-7

Minimate pro User Guide (online: https://www.instantel.com/media/436/download)