Analysis of Rock Blasting Adjacent to WCPA Water Main and Eversource Transmission Line Supports at the Gales Ferry Intermodal Industrial Site

Submitted to

Mr. Chase Davis

Gales Ferry Intermodal LLC
1761 CT12
Gales Ferry CT

Submitted by

Dr. Catherine Aimone-Martin

Aimone-Martin Associates, LLC
New Mexico

September 11, 2024

Project Description

Gales Ferry Intermodal LLC plans to engage in the industrial regrading of a 40-acre site in Gales Ferry, CT to create 26 acres of developable industrial land. The existing hill will be excavated by benching the bedrock and the rock material will be removed from the site. The development will preserve the Mount Decatur historic site and take into consideration the protection of utilities surrounding the site.

This report summarizes a study of controlled rock excavation by blasting designed to protect the WPCA water main to the east of the project buried along CT 12 and the Eversource power line pole supports running along the southern boundary.

Aimone-Martin worked closely with Loureiro Engineering Associates to identify the locations of the transmission line supports and the buried water line with respect to the perimeter of planned rock excavation. Details of rock blasting designs to protect off-site utilities and other structures beyond the perimeter were discussed at length with Maine Drilling & Blasting (MD&B) blasting personnel. Specifically, an approach to mitigating ground strains in terms of velocity that may propagate from the blast sites was established for the loading of blasting agents within both perimeter (pre-split) and production drill holes. The science of ground motion propagation from blast holes is well known and modeled to a high degree of accuracy. A highly conservative site model was selected to design blasting and predict ground motions generated from the site perimeters as a means to mitigate and control off-site effects of vibrations to utilities.

This report summarizes the mitigated impacts to the water line and transmission line supports by considering limits to ground motions that are both protective of the utilities and comply with protocols and requirements specified in Eversource documents contained in the references herein. Details of the water line with respect to burial depth, pipe material, and operating pressures were provided from WCPA via Loureiro Engineering Associates. The pipeline analysis herein complies with industry standards for blasting adjacent to all buried lines. Calculations to show compliance for transmission line supports in terms of ground peak velocities and for the pipeline in terms of ground strains are provided herein.

Site conditions

A site map is provided in Figure 1 showing the locations of the perimeter blasts closest to the WCPA water line at 107 ft and Eversource supporting poles with the closest distance taken as 70 ft, each from the planned highwall crest. Close-in plan views and precise distances to utilities were provided by Loureiro Engineering Associates and shown in Figures 2 and 3 for the water line and support poles, respectively. Figure 4 depicts a section profile of the upper benches designed near the closest distance of perimeter blasting to the water line of 107 ft.

Perimeter blasting along the design highwall will employe pre-split methods with reduced charge weights to control and protect slope stability. The adjacent row of holes represents production blast holes with higher charge weights at a specific burden distance to achieve desired rock fragmentation. The charge weights used in the production holes were used to compute ground motions to ensure protection of utilities.

Blast designs considered site geology comprising a gneissic rock overlying granite. The drill log information provided by Continental Placer Inc. shows 100% core recovery with cores containing very few fractures. Although no mechanical properties were provided, Aimone-Martin has extensive experience blasting in hard New England rock and used this experience with MD&B in the preliminary planning of blast designs with rock strength and ground excitation frequencies in mind.

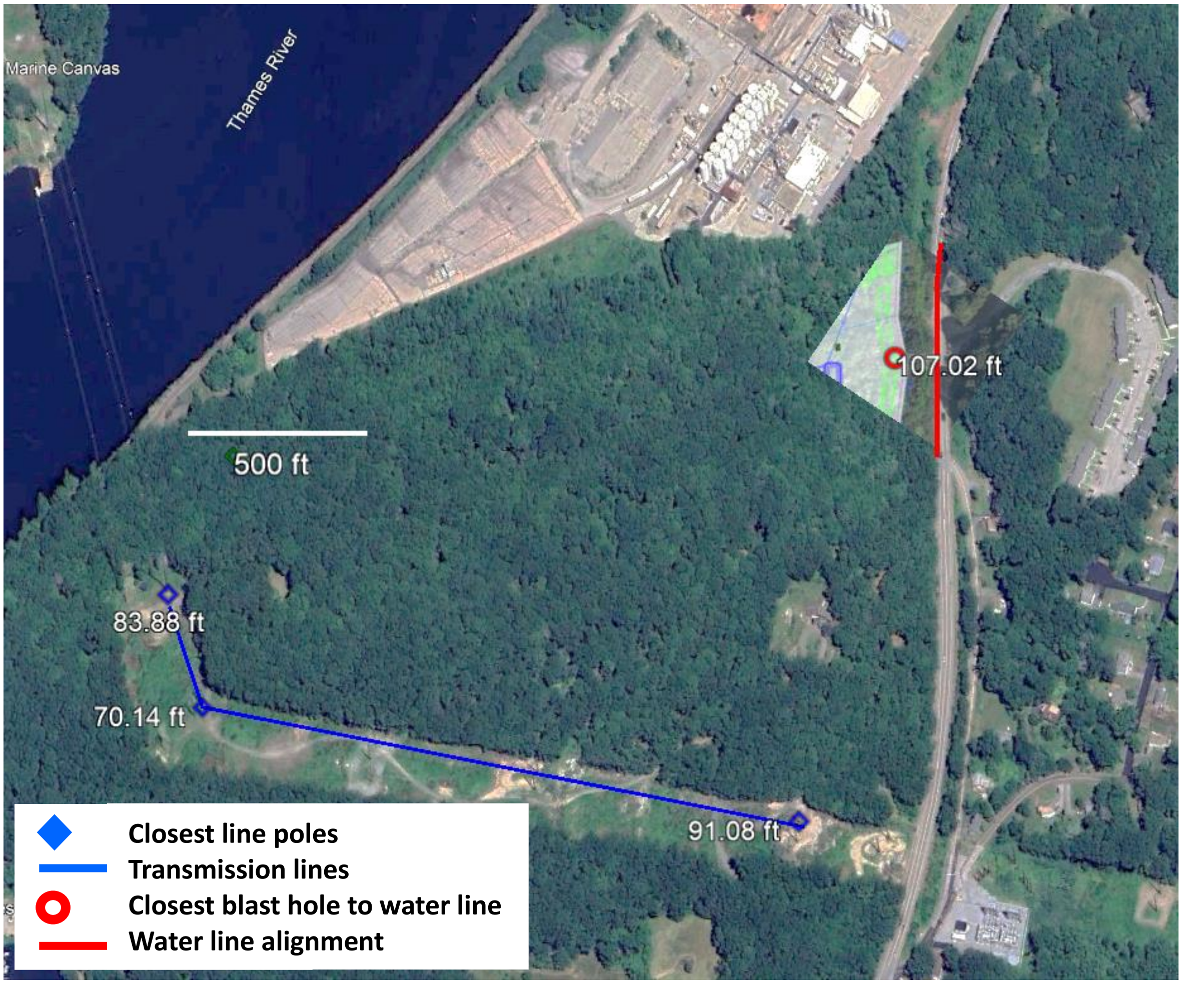

Figure 1. Site location showing the WCPA water line and the location of the closest planned blasts 107.02 ft to the west and the locations of three transmission line poles closest to planned blasts at 70.14 ft, 83.88 ft and 91.08 ft. All distances are measured to the crest of the top bench where the closest perimeter blast holes will be drilled.

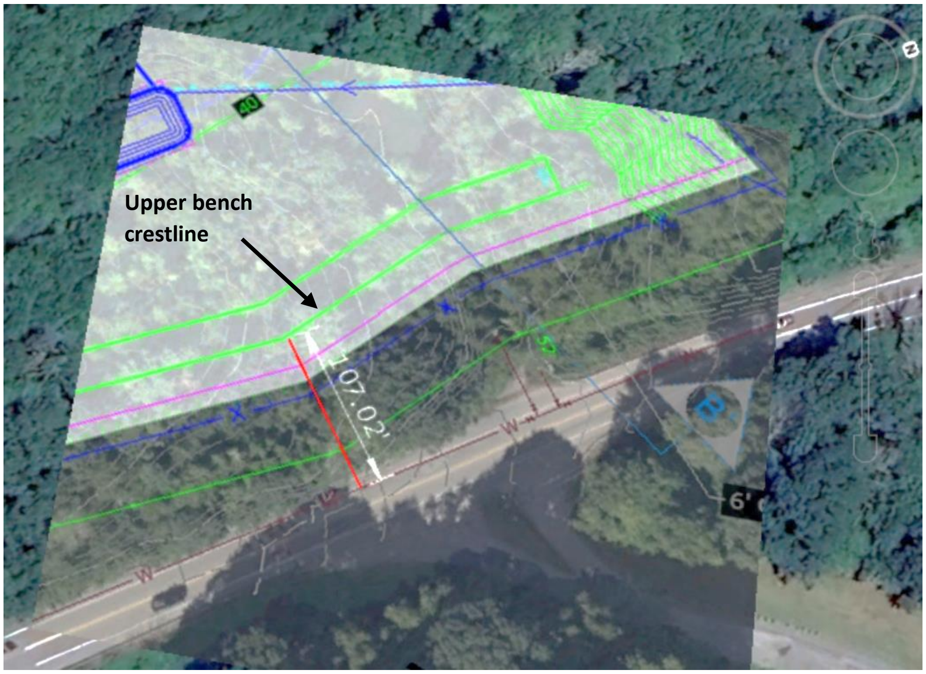

Figure 2. Distance to the WCPA waterline marked as "W" along CT12 from the line of perimeter drill holes marking the crestline of the upper bench.

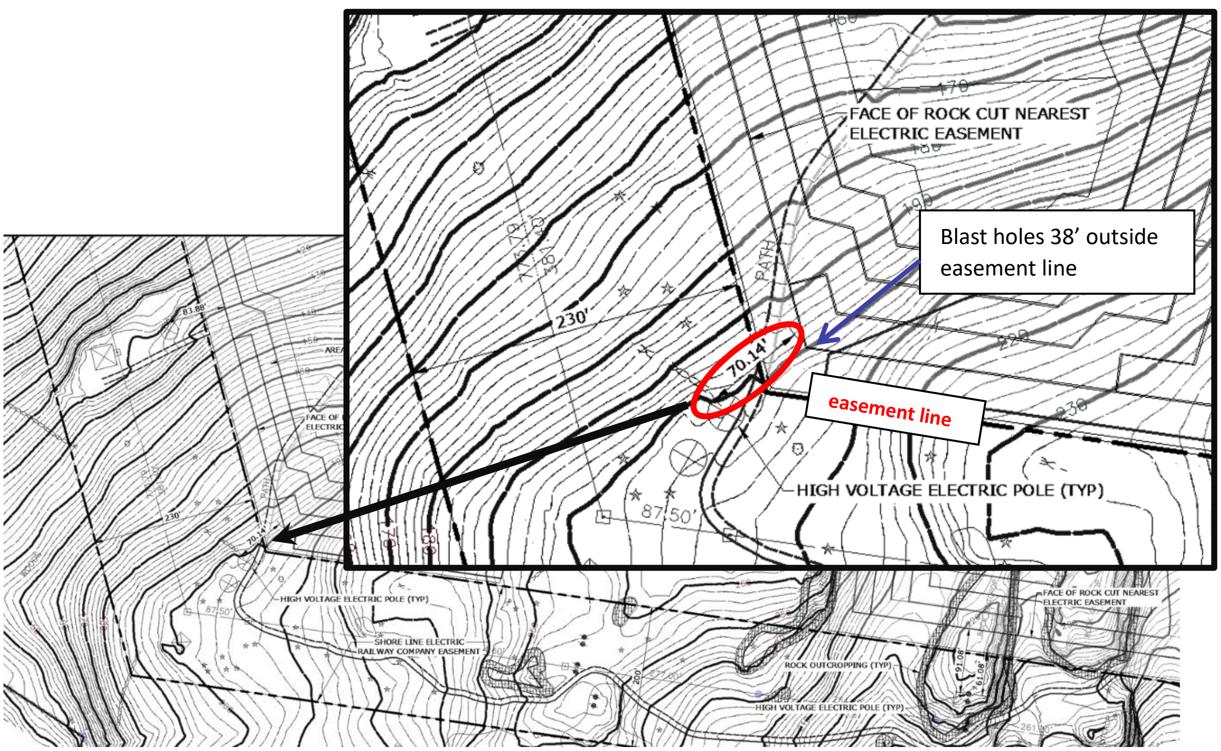

Figure 3. Engineer drawing of excavation benches along the site south perimeter showing the closest blast hole distance to the transmission line support poles of 70 ft that is approximately 38 ft outside of the easement.

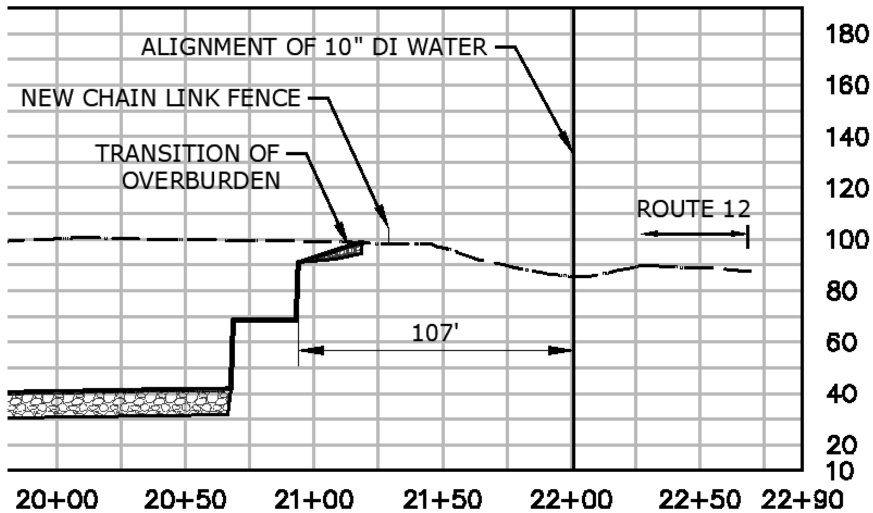

Figure 4. Cross-section view looking north of the typical planned perimeter rock cut at the closest distance to the WCPA water line showing the 20-foot upper bench face from elevation 70 to 90 and lower bench 30-foot face from elevation 40 to 70; upper bench crest is 107 ft from the WCPA water line along the western edge of CT 12.

Assessments of controlled rock blasting in the vicinity of utilities

1. Eversource transmission line support structures

Eversource 115-kV transmission line supports closest to the planned blasting are shown in Figure 5. Supports appear to be tubular monopole anchored in the ground with concrete. The line of planned perimeter blast holes is 70 ft to the closest support and 38 ft outside the Eversource easement as shown in Figure 3.

Requirements for blasting in the vicinity of Eversource transmission lines are documented in ORTM 050 and 250 with vibration limits outlined in OTRM 251. These limits are shown in Table 1. We have reviewed these limits and other requirements for blast planning. Although blasts fall outside the easement, we are prepared to meet the OTRM requirements in the proximity to the easement shown in Figure 3. Blasting experience in this rock formation has shown that the dominant frequency is 40 Hz. Therefore the “Limiting PPV” value of vibrations will be held to 1.0 in/s for perimeter blasting near the transmission lines.

To meet this criteria, the predicted ground vibrations in terms of PPV were computed using the following attenuation or propagation model

$$PPV = K\,(SD)^{-b} \qquad (1)$$

where SD is scaled distance defined as the distance (D) from the closest blast hole to a specific location of interest (in this case the closest pole at 70 ft), divided by the square-root of the maximum explosives charge weight (W) planned for the closest production blast hole. The attenuation model constants K and -b developed several decades ago for construction blasting in hard rock are 160 and -1.60. These constants are highly conservative and used herein to establish preliminary blast design charge weights until site test blasts can be conducted to develop site-specific model constants.

 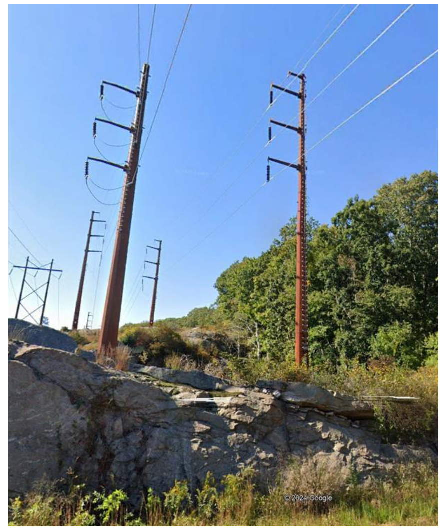

Figure 5. Eversource steel support structures adjacent to planned blasting that will take place to the right in each photograph.

Table 1. OTRM 251 guidance for drilling and blasting in the vicinity of Eversource property.

Vibration Type	Threshold PPV	Limiting PPV
Steady State	0.2 ips for frequencies less than 30 Hz	0.5 ips for frequencies less than 30 Hz
	0.5 ips for frequencies greater than 30 HZ	1.0 ips for frequencies greater than 30 HZ
Impact	0.5 ips for frequencies less than 60 Hz	1.0 ips for frequencies less than 60 Hz
	1.0 ips for frequencies greater than 60 Hz	2.0 ips for frequencies greater than 60 Hz

Proposed blast designs for the closest perimeter line of pre-split holes and production holes one burden distance away from the pre-split holes in line with the support pole 70 ft away are summarized in Table 2. In each case the predicted PPV is less than 1.0 in/s and within Eversource limits for transmission support poles.

MD&B blast designers are confident that rock removal at this distance using the unit charge weights per time delay noted will sufficiently fragment the rock for excavation while meeting the PPV limits imposed by Eversource.

Table 2. Proposed controlled blast design for a 70-ft distance to the closest Eversource steel support structure.

		Eversource overhead transmission line	
		Pre-split	Production
Distance to utility	(ft)	70	76
Blast design charge weight per time delay	(lb)	8.08	9.58
Scaled distance	($ft/lb^{1/2}$)	24.6	24.6
Peak particle velocity (PPV)	(in/s)	0.95	0.95

2. WCPA water line

Blasting in the vicinity of buried pipelines requires a special analysis that considers the blast-induced increase in pipe wall hoop and elongation tensile stresses along the pipe alignment which is additive to normal operating stresses to form the total combined stresses in the pipe wall. The allowable wall hoop stress based on pipeline material strength reduced by an appropriate design factor is divided by the total combined stresses to compute the factor of safety that includes blasting forces on the pipe wall.

The pipe strength parameters were determined based on correspondence dated May 28, 1997 from Amory Engineers obtained from Loureiro Engineering. The nominal 16-inch diameter water main along CT 12 was most likely constructed in 1997 and manufactured by Atlantic States Cast Iron Company. The pipe comprises ductile iron (DI), Class 52 pipe with a 350 psi pressure rating and a wall thickness of 0.4 in.

The DI pipeline material and operating properties are given in Table 3. The operating pressure is assumed to be 110 psi and up to 125 psi. A conservative surge pressure of 25 psi was added to a 110 psi pressure. The operating factor of safety (FOS) in the absence of blasting is 10 as shown in Table 3 based on the allowable hoop stress divided by the maximum operating hoop stress at the time of a surge. Note the yield strength is reduced by 28% which is an added FOS.

Table 4 provides the assumed granite bedrock wave speeds needed to compute ground strains as a function of vibrations in the rock. It is assumed, in the worst case, that ground strains transfer directly into the pipe walls. The average ground motion frequency of 40 Hz is typical of granite and used to compute the maximum ground displacement associated with the PPV of 2.8 in/s.

The calculated peak particle velocity (PPV) from the closest production blast hole is shown in Table 5 as 2.8 in/s. This was computed using equation (1) where the planned design charge weight per time delay provided by Maine D&B is 84.09 lbs and the distance from the pipe to the first row of production holes is 115 ft (107 ft to the pre-split holes plus 8 feet of burden distance to the production holes).

$$PPV = 160\,[(115/(84.09)^{1/2}]^{-1.6} = 2.8 \text{ in/s} \quad (1)$$

Table 3. WCPA water line assumed material properties and operating pressures.

PIPE PARAMETERS	Symbol	Units	Ductile Iron
Pressure Class (psi)			Class 52 DI
Pipe OD	Do	in	17.4
pipe ID (size)	Di	in	16
Wall thickness - nominal	t	in	0.4
Inside radius	r		8
Young's modulus	E	psi	24,000,000
Bulk Modulus	G	psi	17300000
Poisson's ratio	υ		0.27
Tensile strength	UTS		60,000
Yield Strength in tension	SMYS	psi	42,000
Design Factor	DF	generally 0.5-0.8 (0.72 typical)	0.72
Allowable hoop stress in the pipe	$\sigma_{h\text{-}allow}$ = SMYS * DF	psi	30240
Longitudinal operating stress	$\sigma_{L\text{-}allow}$ = MAOP * OD /4 t	psi	15120
Operating pressure	OP	psi	110
Allowable internal pressure MAOP (<design)	(2*t*UTS*F) / OD	psi	1390
Surge pressure	SP	psi	25
Operating hoop stress in pipe	σ_{OP} = [(OP+SP)*Do] / [2*t]	psi	2936
Operating factor of safety	FOS = $\sigma_{allow} / \sigma_{op}$		10

Table 4. Estimated wave speeds for granite rock.

ASSUMED ROCK PROPERTIES - granite			
compression wave velocity	C_c	ft/s	19000
shear wave velocity	C_s	ft/s	11000
dominate frequency	F	(Hz)	40

Table 5. Calculated peak particle velocity in the ground at the pipeline from the closest production blasthole at 115 ft from the pipeline.

		WCPA water line	
		Pre-split	Production
Distance to utility	(ft)	107	115
Blast design charge weight per time delay	(lb)	8.41	84.1
Scaled distance	($ft/lb^{1/2}$)	36.9	12.5
Peak particle velocity (PPV)	(in/s)	0.50	2.80
Expected peak displacement PPV/(2*π*F)	(in)		0.011

Table 6. Longitudinal hoop strains imposed on the pipeline from production blasting.

STRAINS ON PIPELINE FROM BLASTING (in/in)		**Computed**
longitudinal ε_L	$\frac{PPV}{12*Cc}$	0.000012
circumferential or hoop ε_c	[PPV / (12*Cs)] [1 + (3t/Do)] or PPV/ 12*Cs	0.000023

The peak displacement in the ground is expected to be 0.011 in which is 2.75 times the thickness of a piece of writing paper that is 0.004 in thickness. This amplitude of ground displacement is extremely small and ground movement as well as wall deflections to the DI water pipeline are expected to be barely detectable.

The calculated longitudinal (elongation) and hoop strains in the pipeline walls from a PPV of 2.8 in/s are shown in Table 6 and computed with respect to wave speeds in compression (longitudinal direction of wave propagation, Cp) and shear (transverse to wave travel direction, Cs). The strains are computed as 12 and 23 micro-strains in axial and circumferential directions respectively. These amplitudes are extremely small and well within safe limits for pipe wall strains.

The factor of safety (FOS) analysis combining operating and blasting stresses is given in Table 8. The FOS combines the effects of axial and hoop strains to arrive at a blasting FOS of 8.9. This FOS is extremely safe and only slightly less than the FOS calculated for internal operating pressures alone of 10.

Table 8. Blast-induced stresses in the pipeline wall and resulting factor of safety (FOS) resulting from combine operating and blast-induced stresses.

FACTOR OF SAFETY ANALYSIS		surface predicted
Blast-induced stresses (psi)		
longitudinal stress σ_L	$[E / (1-\upsilon^2)] [\varepsilon_L + \upsilon\varepsilon_C]$	476.1
circumferential or hoop stress σ_h	$[E / (1-\upsilon^2)] [\varepsilon_C + \upsilon\varepsilon_L]$	672.3
FOS analysis		
Combined hoop stress at OP and blast circumferential stress (psi)	$(\sigma_{OP} + \sigma_h)$	3609
Total Combined stress von Mises criteria (psi)	$(\sigma_{TOT}{}^2 - \sigma_{TOT} * \sigma_L + \sigma_L{}^2)^{0.5}$	3396
Blasting FOS	σ_{allow}/ VonMises Stress	8.9

Summary

Blasting designs provided by Maine D&B were used to predict ground motions in the vicinity of the Eversource transmission support poles and at the WCPA water pipeline buried along CT 12. The closest distance from blasting and design charge weights planned for the production blast holes were used to assess the impacts of blasting on the utilities. In each case, the predicted ground vibrations were well within safe limits to protect the WCPA buried pipeline and the Eversource poles and met required limits for the power line supports.

It is concluded that rock blasting planned for the Gales Ferry Intermodal Industrial Site development is deemed highly safe and protective of the surrounding infrastructure and utilities.

References

EVERSOURCE Overhead Transmission Line Standards: Technical guidelines and requirements for drilling and blasting in the vicinity of Eversource property.

- OTRM 050 Guidelines For Blasting Near Utilities
- OTRM 250 Construction and Commissioning Standards
- OTRM 251 Construction: Section E.1c allowable peak particle velocity