RESOLUTION COPPER

NOISE & VIBRATION ASSESSMENT – RESOLUTION COPPER UNDERGROUND TO SURFACE CONVEYOR SYSTEM – APACHE LEAP SPECIAL MANAGEMENT AREA

Submitted to:

Resolution Copper
P.O. Box 1944
Superior, Arizona, USA
85173

Submitted by:

Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited
160 Traders Blvd., Suite 110
Mississauga, Ontario
L4Z 3K7

February 10, 2017

TC160807

February 10, 2017

Ref: TC160807

Andrew Luke
Resolution Copper
P.O. Box 1944
Superior, Arizona, USA
85173

Dear Mr. Luke,

Noise & Vibration Assessment – Resolution Copper Underground to Surface Conveyor System – Apache Leap Special Management Area

Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler), is pleased to provide this noise and vibration assessment for the construction and operation of the proposed underground ore conveyor and tunnel at the Resolution Copper facility in Superior Arizona.

We greatly appreciate the opportunity to provide support for the Resolution Copper Project. Should you have any questions regarding the study, please do not hesitate to contact us.

Yours truly,

AMEC Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Buddy Ledger, M.A.Sc., P.Eng., INCE
Acoustics Group Leader / Senior Acoustics Engineer

402 W. Main Street
Superior, Arizona
+1 (520) 689 9374

February 13, 2017

Ms. Mary Rasmussen
US Forest Service
Supervisor's Office
2324 East McDowell Road
Phoenix, AZ 85006-2496

Subject: Resolution Copper Mining, LLC – Mine Plan of Operations and Land Exchange – Noise & Vibration Assessment of Underground to Surface Ore Tunnel & Conveyor System

Dear Ms. Rasmussen,

As requested, a noise and vibration assessment for the construction and operation of the underground to surface ore tunnel and conveyor system in relation to the Apache Leap Special Management Area has been conducted. Enclosed with this letter please find two DVD's which contain this report.

Should you have any questions or require further information please do not hesitate to contact me.

Sincerely,

Vicky Peacey,
Senior Manager, Permitting and Approvals; Resolution Copper Company, as Manager of Resolution Copper Mining, LLC

Cc: Ms. Mary Morissette; Senior Environmental Specialist; Resolution Copper Company

Enclosure(s): Resolution Copper Mining, LLC – Noise & Vibration Assessment of Underground to Surface Ore Tunnel & Conveyor System 02-13-2017(2)

EXECUTIVE SUMMARY

Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler), at the request of Resolution Copper has prepared this noise and vibration assessment for the construction and operation of the proposed underground ore conveyor and tunnel at the Resolution Copper facility in Superior Arizona. The proposed underground conveyor route is shown in Figure 1.

This report specifically deals with the potential impacts of noise and vibration on the Apache Leap Special Management Area (SMA) due to the construction and operation of the proposed underground inclined conveyor system for the Resolution Copper facility.

The findings of the noise and vibration assessment indicated when considering the impact on the SMA only, and considering no other constraints or sensitive land-uses:

Blasting:

- At the minimum slant distance between the tunnel and the SMA boundary (1,536 feet) the blast loading should be kept below 37 kg TNTe/delay until blast vibration monitoring is conducted to evaluate the potential to increase this constraint;
- At the eastern portion of the tunnel where the slant distance is greater the blast loading can be increased to 192 kg TNTe per delay until blast vibration monitoring is conducted to evaluate the potential to increase this constraint; and,
- Vibration and overpressure emissions from blasting with as much as 380 kg TNTe/delay, at the vent raise and portal locations, are not expected to exceed the applicable vibration and overpressure limits of 0.1884 in/sec and 120 dBL, respectively, at the SMA boundary.

Operations:

- Significant ground vibration emissions are not expected from the operational conveyor system
- Noise levels at the SMA boundary generated by the operational conveyor are expected to be well below the regulatory limits.

TABLE OF CONTENTS

PAGE

LIST OF FIGURES (Located in Appendix A and B)

LIST OF APPENDICES

1.0 INTRODUCTION

Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited (Amec Foster Wheeler), at the request of Resolution Copper has prepared this noise and vibration assessment for the construction and operation of the proposed underground inclined ore conveyor and tunnel at the Resolution Copper facility in Superior Arizona. The proposed underground conveyor route is shown in Figure 1.

This report specifically deals with the potential impacts of noise and vibration on the Apache Leap Special Management Area (SMA) due to the construction and operation of the proposed underground inclined ore conveyor and tunnel at the Resolution Copper facility.

2.0 BACKGROUND

The construction of the underground tunnel where the conveyor will reside is to originate at the West Plant Site portal and continue to approximately 3,400 feet below grade at the underground mine (see Figure 2). The tunnel will proceed south (approximately 0.6 miles) underground from the portal to a vent raise at which point the tunnel will be approximately 400 feet below grade. At the vent raise the tunnel will turn east (approximately 2.1 miles) toward the East Plant Site production shafts.

The tunnel will contain a conveyor to transport ore from the underground mine production shafts to the Concentrator at the West Plant Site.

The tunnel will be constructed using industry standard methods utilizing underground drilling and explosive blasting. Underground explosive blasting, when required, will utilize underground drilling rigs (drilling jumbos) to drill blast holes. Once drilled the blast holes are filled with explosive and prepared for a blasting round. This process is repeated for successive rounds of blasting to progressively advance along the length of the proposed tunnel until completion.

3.0 CONSTRUCTION

The tunnel excavation will utilize industry standard underground drilling and explosive blasting which is known to generate ground borne vibration and air overpressure emissions. Noise and vibration evaluations based on this underground tunnelling method consider a maximum potential impact during construction. The tunnel is anticipated to be constructed progressively over a three-year duration with daily blasting and tunnel advance; however, further development of the construction plans and schedules may increase or reduce this duration.

The preliminary evaluation of total explosive charge required for a 4-meter advance of the tunnel is 448 to 838 pounds (203 to 380 kg[1]) of emulsion to excavate the tunnel. Each blasting

[1] Based on 4-meter advance per blasting with a 5 meter x 5 meter cross-section tunnel. The powder

event will be conducted with multiple delays using smaller charges. The detailed construction and blasting plans will be developed and refined as the design advances and construction commences. This report will discuss the initial explosive loading limitation per delay based on surface vibration levels until blast pattern and monitoring can be established during construction. The explosive mass loading has been evaluated in terms of Trinitrotoluene equivalent explosive (TNTe). Emulsion explosives typically have a relative effectiveness factor which is less than 1 kg TNTe/kg. Therefore, in most cases 1 kg TNTe will translate into slightly larger than 1 kg of emulsion (subject to manufacturer specific data). Emulsion explosives come in a variety of formulations and therefore manufacturer specific data will be required to convert loadings from kg TNTe to the site specific explosive proposed. This is discussed further in Section 5.0.

3.1 Blasting Vibration

Blasting will be conducted along the entire tunnel alignment. As construction progresses underground, each blasting event will generate underground vibration emissions which will propagate through the ground. Therefore the worst case vibration impacts are expected when the slant distance from the tunnel to a receiver location is the shortest.

3.1.1 Applicable Guidelines

The effects of vibration from blasting on structures and human annoyance are discussed in the U.S. Dept. of the Interior, Bureau of Mines (USBM) Report of Investigations RI 8507 [1]. RI 8507 concludes that safe levels of blasting vibrations for residential type structures at low frequencies (< 40 Hz) are below 0.5 in/sec and at high frequencies (≥ 40 Hz) are below 2 in/sec. These levels relate to the effects on residential structures and the probability of damage. The criteria presented in the main text of RI 8507 is further expanded in Appendix B of the same document. The purpose of Appendix B was to eliminate the sharp discontinuity in the peak particle velocity criteria at 40 Hz by introducing displacement constraints. Appendix B of RI 8507 defines the safe levels of blasting vibrations for residential type structures as 0.1884 in/sec at 1 Hz, increasing to 0.5 in/sec at 2.7 Hz, remaining at 0.5 in/sec up to 10 Hz, increasing to 2 in/sec at 40 Hz and remaining at 2 in/sec up to 100 Hz.

RI 8507 concludes that particle velocities of 0.5 in/sec should be tolerable to about 95 percent of the people perceiving it as “distinctly perceptible”. However, complaints could be significant if the vibration actually interferes, or is perceived to interfere, with activities such as sleep, speech, entertainment, etc. Complaints associated with blasting will also increase due to fright or being startled in those people not expecting or aware of the blasting activity. Therefore, RI 8507 emphasizes the value of good public outreach and communication on the part of the blaster to mitigate these effects.

---

factor considered is a range from 2.03 to 3.8 kg/BCM.

3.1.1.1 Summary of Applicable Limits

Based on the information presented in RI 8507 the most restrictive limits correspond to the low frequency limits which for structures is 0.1884 in/sec (< 3 Hz) and for human perception is 0.5 in/sec. Therefore a limiting value of 0.1884 in/sec is a reasonable worst case and safe limit to use for this analysis and since the blasting is proposed at significant depths, significant low frequency components would be expected. Once blasting commences, site specific measurements of blast vibration frequencies and attenuation factors could be collected and utilized to refine the limits on blast loading and the impact assessment predictions.

3.1.2 Impact Assessment Approach

The vibration emissions are expected to originate at the location of each blast, as blasting progresses along the tunnel alignment, and propagate through the ground. Ground vibration levels from blasting can be estimated using the USBM Bulletin 656 [2] methodology. The USBM methodology for predicting ground vibration uses the equivalent weight of Trinitrotoluene explosive (kg TNTe) as the input variable. Utilizing receptor location data, tunnel alignment data and the vibration criteria; the predictive model can be used to establish the upper limit for explosive loading per delay in terms of kg of TNTe.

3.1.3 Impact Assessment

The minimum slant distance between the tunnel alignment and the SMA boundary is approximately 1,536 feet. This is shown on Section 5 (see Figure 7) of the tunnel profile in Appendix B. At this distance the explosive loading to meet a surface vibration level of 0.1884 in/sec is 37 kg TNTe per delay. If the blasting is found to not generate significant frequency components below 3 Hz then the surface vibration level criteria could be increased to 0.5 in/sec which correspondingly increases the allowable explosive loading to 125 kg TNTe per delay. Once the blasting passes the SMA, the blast loadings may be progressively increased provided there are no other applicable constraints.

Therefore when considering the impact on the SMA only, and considering no other constraints or sensitive land-uses, the blast loading should be limited to 37 kg TNTe per delay at the lowest slant distance at western portion of the SMA and 192 kg TNTe per delay at the eastern portion where the slant distances are the highest unless site specific measurements during tunnel construction show that actual impacts are different than originally modeled.

Copies of the blasting calculations are included in Appendix C along with two blast planning tables; one corresponding to the 0.1884 in/sec low frequency limit, and the other corresponding to 0.5 in/sec high frequency limit.

3.2 Blasting Noise/Overpressure

Overpressure occurs from blasting and is the instantaneous air pressure increase above atmospheric pressure from the detonation of explosives. As such, the effect of blasting overpressure is only expected to be felt at locations in proximity of tunnel opening to the atmosphere such as at the conveyor portal and the vent raise. Further as blasting progresses underground these emissions will be attenuated via propagation along the tunnel. Therefore overpressure impacts are expected at or near the surface and will vary along the length of the tunnel and distance from the portal and vent raise.

3.2.1 Applicable Guidelines

The effects of air overpressure from blasting on structures and human annoyance is discussed in the USBM Report of Investigations RI 8485 [3]. RI 8485 concludes that blast overpressures at receiver locations exceeding 120 dBL will produce some annoyance from rattling and fright, with as much as 5 to 10 percent of homes exhibiting such disturbances at the identified maximum safe level of 134 dBL (when measured with a 0.1 Hz high-pass system). The safe maximum air overpressure values presented in RI 8485 are dependent on the lower frequency limit of the measurement with the lowest limiting value being 129 dBL (using a 5 or 6 Hz high-pass system).

3.2.1.1 Summary of Applicable Limits

Based upon the results presented within RI 8485 a value of 120 dBL represents a reasonable maximum limit on overpressure in order to avoid both structural and human response issues from blasting.

3.2.2 Impact Assessment Approach

Overpressure effects are expected to originate from the conveyor portal and the vent raise. These are at substantial distances from the SMA and are not expected to limit loadings, below those already planned, in order to meet criteria. Air-overpressure estimates from blasting can be calculated using the Linehan and Wiss equation [4]. The Linehan and Wiss equation for predicting overpressure uses the equivalent weight of Trinitrotoluene explosive (kg TNTe) as the input variable.

3.2.3 Impact Assessment

The vent raise location is approximately 5,981 feet from the SMA when measured in plan. The portal location is even farther removed from the SMA. At 5,981 feet, a 380 kg TNTe/delay will produce an air overpressure level of approximately 114 dBL. This is below the applicable limit of 120 dBL. Therefore when considering the impact on the SMA only, and no other constraints or sensitive land-uses, the blast loading of 380 kg TNTe/delay will not produce overpressure levels in excess of the applicable limit of 120 dBL. Copies of the blasting calculations are included in Appendix C.

4.0 OPERATIONS

Operational effects of vibration are not expected and emissions of noise are expected to be localized to the above ground sections of the conveyor system at the northwest of the project area.

4.1 Conveyor Noise

The operational inclined conveyor is not expected to generate notable noise or vibrations to the outside environment where it is within the underground tunnel. Noise is expected where the conveyor is above ground. The area where the conveyor will be above ground is approximately 6,248 feet from the SMA boundary.

4.1.1 Applicable Guidelines

The Pinal County, Arizona, Excessive Noise Ordinance [5] establishes limits for noise within different Zoning District Classifications. The most restrictive of these are the “Residential” limits of 60 dBA (7am-8pm) and 55 dBA (8pm-7am). These limits are expressed in terms of the two (2) minute A-weighted energy equivalent sound level which can be symbolized or abbreviated as $L_{Aeq\text{-}2min}$.

4.1.2 Impact Assessment

The conveyor noise is not expected to represent a significant impact at the SMA because of the distance between the source and the receiver. At 6,248 feet the attenuation provided by typical point source hemi-spherical divergence would be approximately 74 dB (over flat terrain). However, the conveyor is likely to act as an incoherent line source which does not benefit from hemi-spherical divergence at close proximity rather exhibits cylindrical divergence. Despite this behavior, the distance to the SMA is over twice the conveyor length and it is likely that the conveyor could be considered a point source. Source geometry becomes less critical as the distance to the receiver location approaches two times a characteristic dimension of the source. Additionally terrain between the conveyor and SMA changes elevations, adding additional attenuation due to barrier effects.

Noise measurements of the Kennecott Utah Copper – Bingham Canyon Mine, Copperton, Utah, conveyor system were provided to Amec Foster Wheeler by Resolution Copper in the form of a memorandum prepared by Rio Tinto Kennecott [6]. That conveyor operates at a nominal production rate of approximately 140,000 tons per day, which is a higher throughput than anticipated for the Resolution Copper Mine Plan of Operations at 132,000 short tons (120,000 metric tonnes) per day. The noise measurements documented within the aforementioned reports indicated that noise levels were approximately 54 dBA ($L_{Aeq\text{-}15min}$) at a distance of approximately 300 feet. This sound level, when neglecting ground and atmospheric effects, which are by comparison to geometric divergence small, can be converted into a sound power level per 3.28 feet (1 meter) of approximately 78.5 dBA. Using the Resolution Copper conveyor length of 2,263 feet this translates into a sound power level of approximately 107 dBA. Then based again solely on the attenuation provided by divergence, the corresponding sound level at 6,248 feet would be approximately 33 dBA. This level is significantly below the applicable limits of 60/55 dBA. It is important to note that the data used for this assessment is based on the above referenced project conveyor (Kennecott Utah Copper – Bingham Canyon Mine) which includes optional low noise generating equipment (e.g. idlers) and other noise mitigation measures. To obtain similar results as the Kennecott operation, the Resolution Copper facility would require the implementation of similar low noise generating measures.

Therefore, when considering the impact on the SMA only, the operational conveyor system is not expected to represent any notable noise or vibration impact.

5.0 SITE SPECIFIC EXPLOSIVES

The allowable explosive loading in kg TNTe per delay may be converted into the kg of site specific explosive per delay using the actual explosive manufacturer's published relative effectiveness factor (R.E. factor) in units of kg TNTe/kg. This will provide the blasting contractor with generalized guidance which can be utilized to determine the limiting kg/delay explosive loading for any explosive compound. The following equation can be used to convert the allowable loading values into kilograms of site specific explosives per delay.

$$W\left(\frac{kg}{delay}\right) = \frac{W\left(\frac{kg\ TNTe}{delay}\right)}{R.E. factor\left(\frac{kg\ TNTe}{kg}\right)}$$

It is important to note that explosive impacts mainly ground vibration levels may be reduced in certain directions by an optimal design of the drilling pattern and sequential blast initiation. Therefore, the blasting contractor must review the drilling pattern and sequential initiation sequence to make sure that wave reinforcement does not occur.

6.0 CONCLUSIONS

The findings of the noise and vibration assessment indicated when considering the impact on the SMA only:

Blasting:

- At the minimum slant distance between the tunnel and the SMA boundary (1,536 feet) the blast loading should be kept below 37 kg TNTe/delay until blast vibration monitoring is conducted to evaluate the potential to increase this constraint
- At the eastern portion of the tunnel where the slant distance is greater the blast loading can be increased to 192 kg TNTe per delay until blast vibration monitoring is conducted to evaluate the potential to increase this constraint; and,

- Vibration and overpressure emissions from blasting with 380 kg TNTe/delay, at the vent raise and portal locations, are not expected to exceed the applicable vibration and overpressure limits of 0.1884 in/sec and 120 dBL, respectively, at the SMA boundary.

Operations:

- Notable ground vibration emissions are not expected from the operational conveyor system; and,
- Noise levels at the SMA boundary generated by the operational conveyor are expected to be well below the regulatory limits.

7.0 LIMITATIONS

The assessments provided in this report are based on the limited information available as of the date of this report. Once blasting commences site specific measurements of blast noise and vibration frequencies and attenuation factors should be collected and utilized to refine the results of the impact assessment predictions and the associated blast loading limits proposed herein.

8.0 REFERENCES

[1] D. E. Siskind, M. S. Stagg, J. W. Kopp and C. H. Dowding, "Structure response and damage produced by ground vibration from surface mine blasting.," U.S. Dept. of the Interior, Bureau of Mines, Washington, D.C., R8507, 1980.

[2] H. R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, D.C., 1971.

[3] D. E. Siskind, V. J. Stachura, M. S. Stagg and J. W. Knopp, "Structure Response and Damage Produced by Airblast from Surface Mining," U.S. Dept. of the Interior, Bureau of Mines, Washington, D.C., R8485, 1980.

[4] P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," *AIME Transactions,* vol. 272, 1982.

[5] "Pinal County Excessive Noise Ordinance," Pinal County, Arizona, 050306-ENO, 2011.

[6] Rio Tinto Kennecott, "Bingham Canyon Mine - Above Ground Ore Conveyor System Noise Data," South Jordan, Utah, 2017.

9.0 CLOSURE

This report was prepared by Amec Foster Wheeler for the sole benefit of Resolution Copper for specific application to the Resolution Copper Project site. The quality of information, conclusions and estimates contained herein are consistent with the level of effort involved in Amec Foster Wheeler's services and based on: i) information available at the time of preparation, and ii) the assumptions, conditions and qualifications set forth in this document. This report is intended to be used by Resolution Copper only, and its nominated representatives, subject to the terms and conditions of its contract with Amec Foster Wheeler. Any other use of, or reliance on, this report by any third party is at that party's sole risk. This report has been prepared in accordance with generally accepted industry-standard. No other warranty, expressed or implied, is made.

If you require further information regarding the above or the project in general, please contact Buddy Ledger, Senior Acoustics Engineer, at (905) 568-2929. Thank you for the opportunity to be of service to Resolution Copper.

Yours truly,
Amec Foster Wheeler Environment & Infrastructure
a Division of Amec Foster Wheeler Americas Limited

Written by: Buddy Ledger, M.A.Sc., INCE
Acoustics Group Leader / Senior Acoustics Engineer

Signature: ______________________ Date: February 10, 2017

Reviewed by: Alfredo Rodrigues, EngSci
Senior Acoustics Specialist

Signature: ______________________ Date: February 10, 2017

P:\2016\Projects\TC160807_Amecfw_Resolution_Copper_Blasting\02_Work_Files\Report\00-Report SMA\01_FINAL\TC160807_Resolution_SMA_FINAL-Signed.Docx

Appendix A: Figures

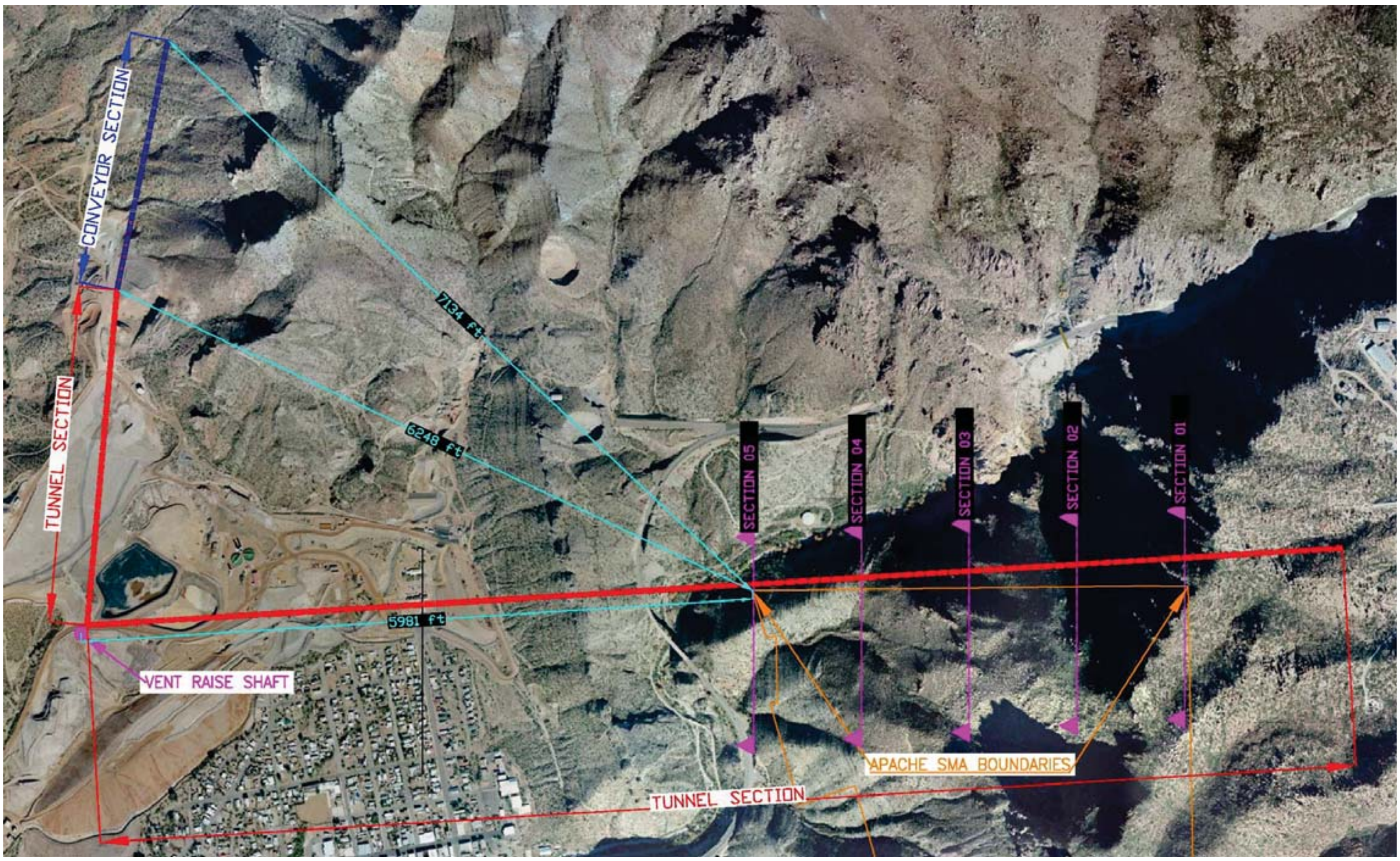

Figure 1: Site Plan

Appendix B: Tunnel Profile and Cross Sections

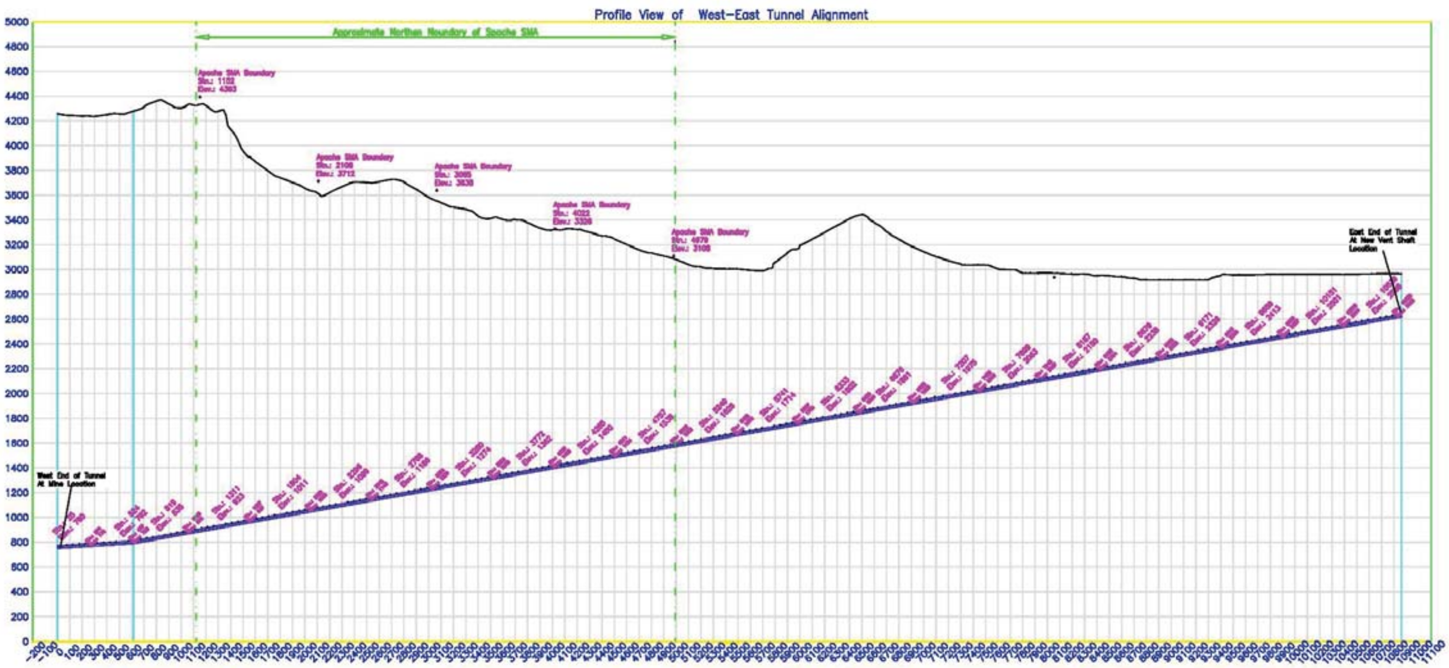

Figure 2: Longitudinal Profile Along West-East Tunnel Alignment

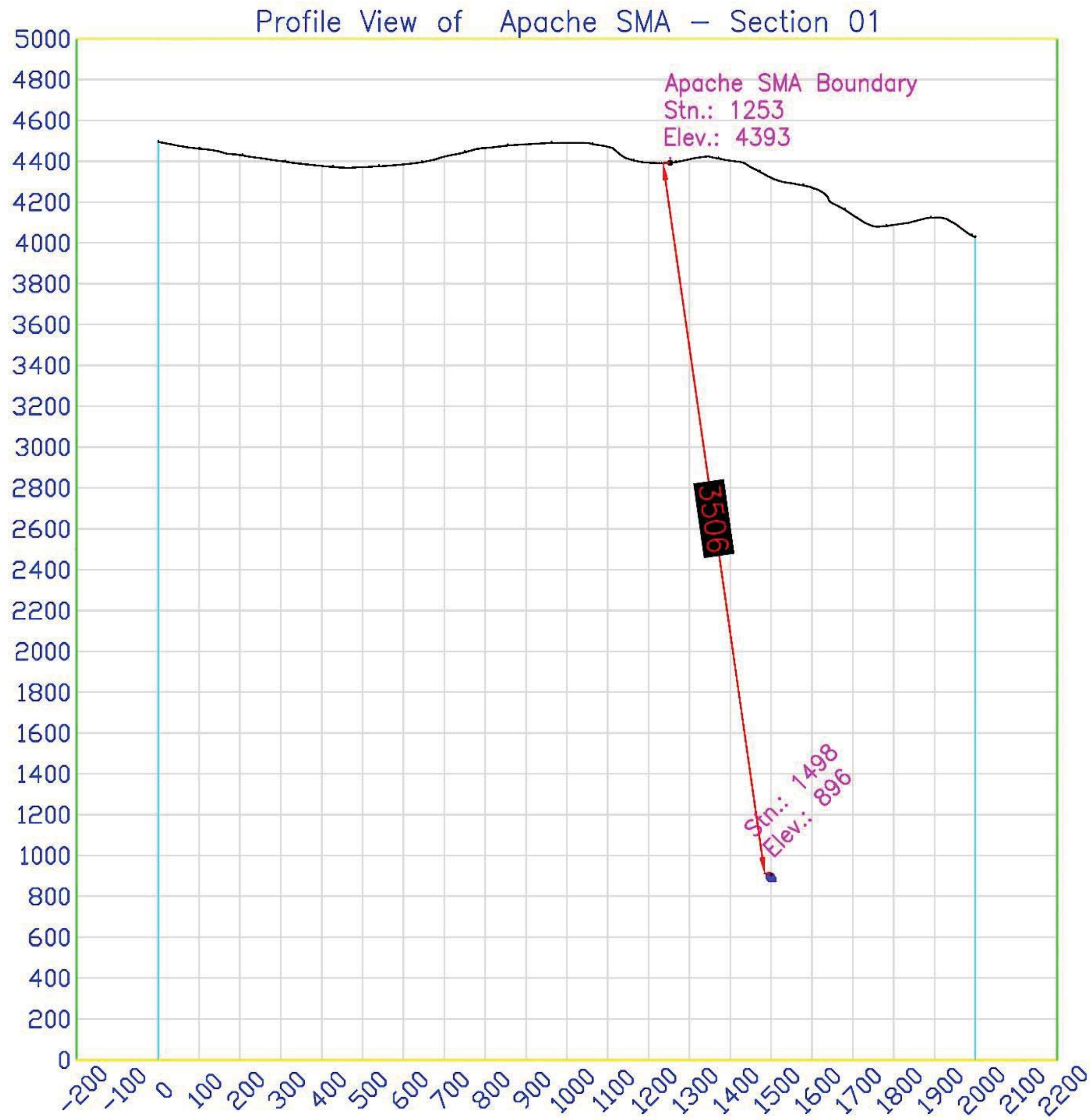

Figure 3: Cross Section Along Section 01

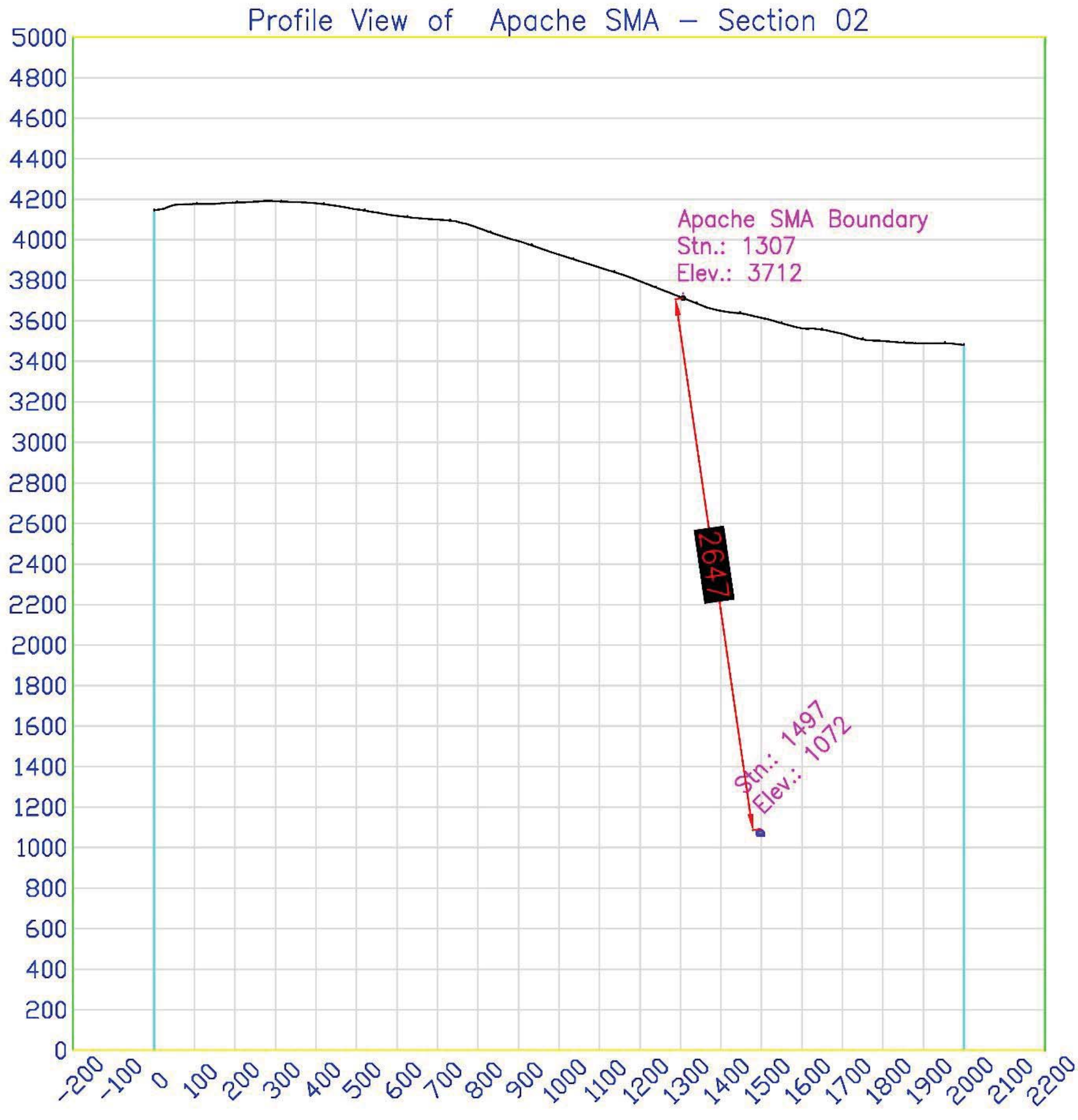

Figure 4: Cross Section Along Section 02

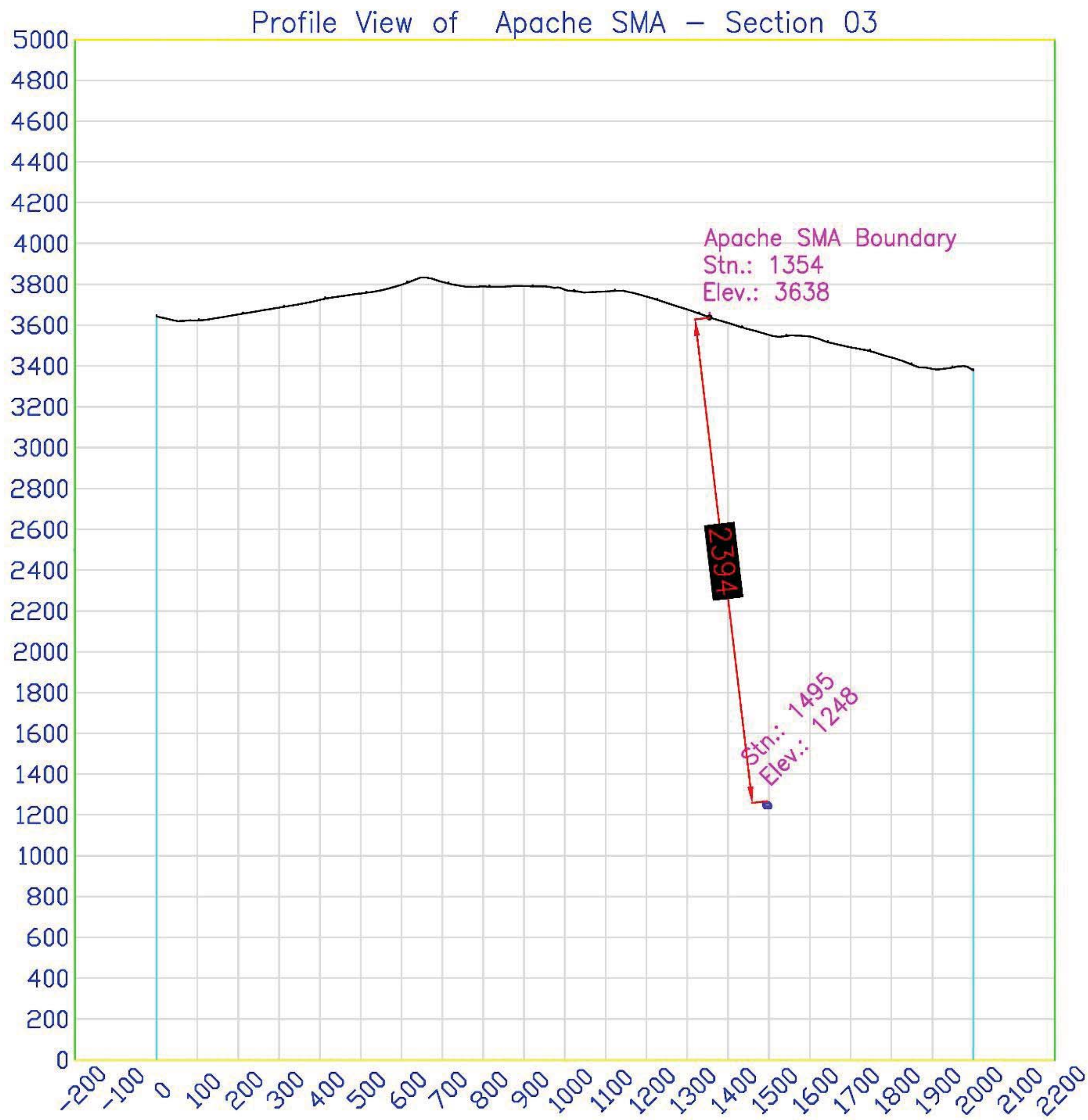

Figure 5: Cross Section Along Section 03

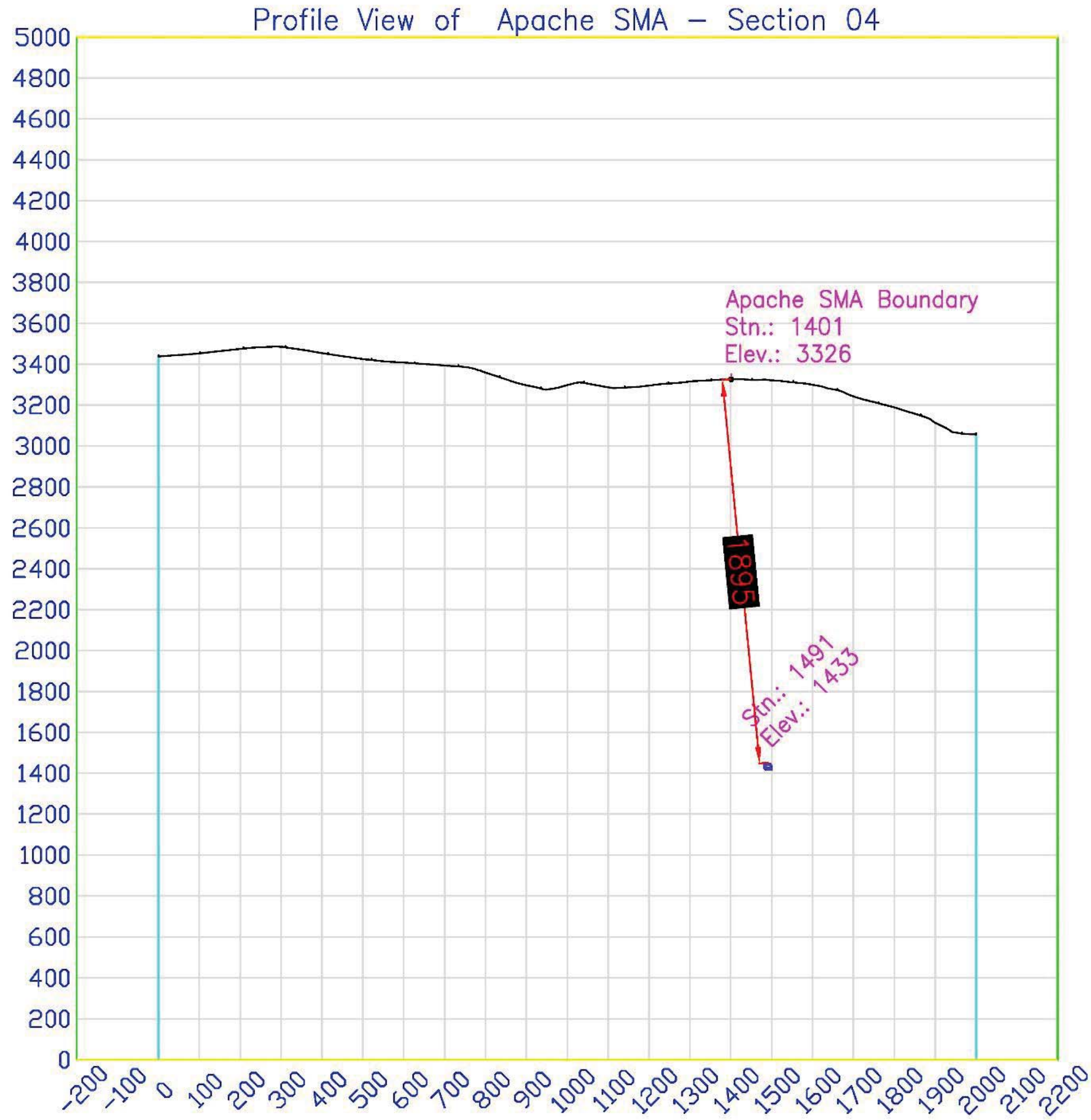

Figure 6: Cross Section Along Section 04

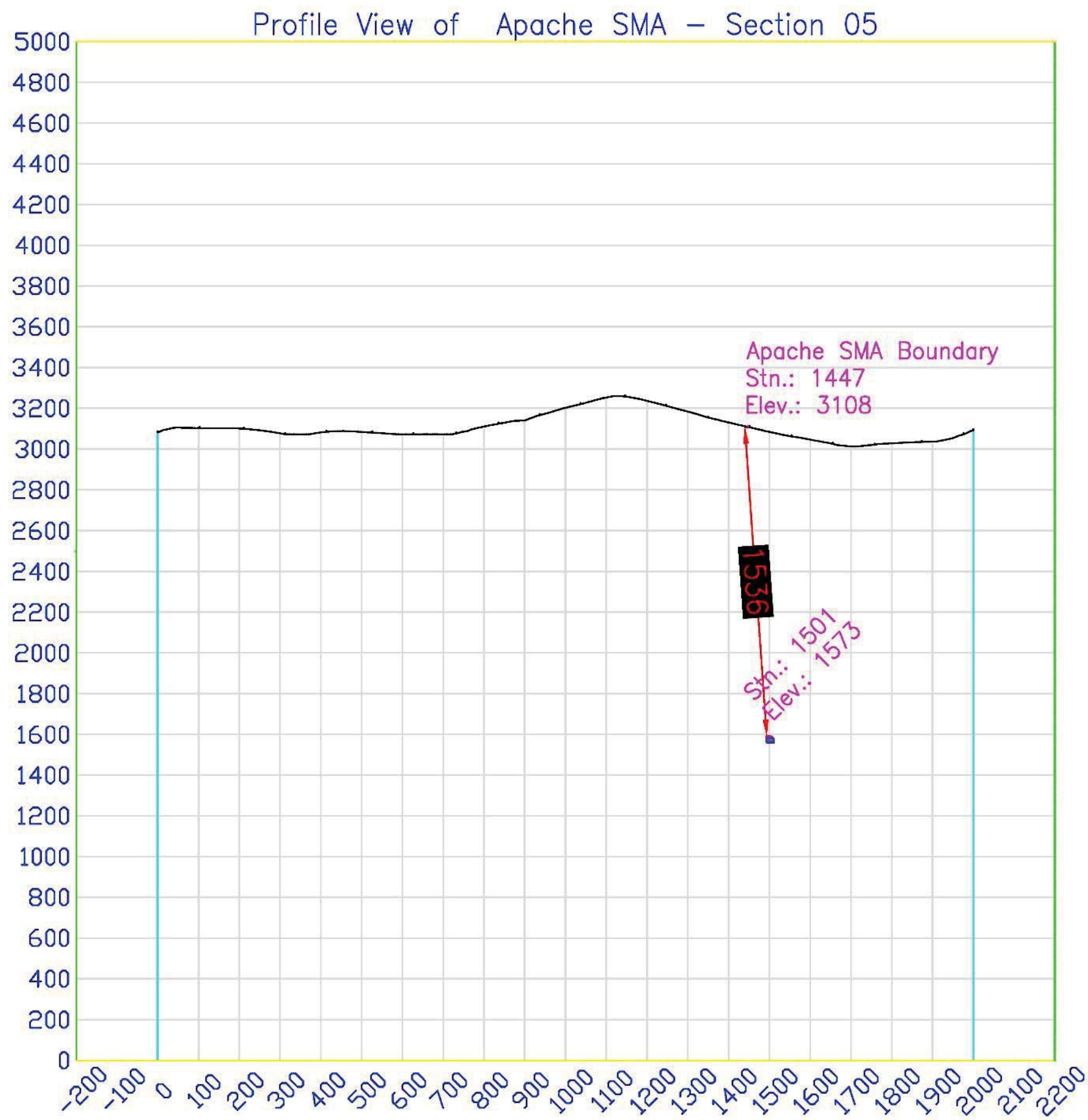

Figure 7: Cross Section Along Section 05

Appendix C: Blasting Calculations

USBM Blasting Calculation Sheet

Project Name:	Resolution Copper
Scope of Work:	Tailings Conveyor/Tunnel
Calculation:	Specified Slant Distance - Output Load
Calculation Identidier:	Calc1.A

Inputs

Distance	D	468	m	1536	ft
Site Constant	k	5000			
Site Exponent	e	1.6			

Limits

Vibration Limit	PPV	4.79	mm/s	0.1884	in/sec

Results

Required charge limit	37	kg TNTe / delay

Calculation based on USBM Bulletin 656 formula for calculation of vibration levels

References

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name: Resolution Copper

Scope of Work: Tailings Conveyor/Tunnel

Calculation: Specified Slant Distance - Output Load

Calculation Identidier: Calc1.A

Inputs

Distance	D	468	m	1536	ft
Site Constant	k	5000			
Site Exponent	e	1.6			

Limits

Vibration Limit	**PPV**	12.7	**mm/s**	0.5	**in/sec**

Results

Required charge limit		125	**kg TNTe / delay**

Calculation based on USBM Bulletin 656 formula for calculation of vibration levels

References

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name:	Resolution Copper
Scope of Work:	Tailings Conveyor/Tunnel
Calculation:	Specified Blast Load - Output Slant Distance
Calculation Identidier:	Calc2.A

Inputs

Weight of Explosive per Delay	W	380	kg TNTe		
Site Constant	k	5000			
Site Exponent	e	1.6			

Limits

Vibration Limit	**PPV**	4.79	**mm/s**	0.1884	**mm/s**

Results

Required slant distance		1502	**metres**	4927	**feet**

Calculation based on USBM Bulletin 656 formula for calculation of vibration levels

References

P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," AIME Transactions, vol. 272, 1982

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name:	Resolution Copper
Scope of Work:	Tailings Conveyor/Tunnel
Calculation:	Specified Blast Load - Output Slant Distance
Calculation Identidier:	Calc2.B

Inputs

Weight of Explosive per Delay	W	380	kg TNTe		
Site Constant	k	5000			
Site Exponent	e	1.6			

Limits

Vibration Limit	**PPV**	12.7	**mm/s**	0.5	**mm/s**

Results

Required slant distance		816	**metres**	2676	**feet**

Calculation based on USBM Bulletin 656 formula for calculation of vibration levels

References

P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," AIME Transactions, vol. 272, 1982

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name:	Resolution Copper
Scope of Work:	Tailings Conveyor/Tunnel
Calculation:	Specified Distance/Loading - Output SPL
Calculation Identidier:	Calc3

Inputs

Distance to Blasting	D	1823	m	5981	ft
Weight of Explosive per Delay	W	380	kg TNTe		
Weight Center of Gravity of Charge	C	2.5	m		
Scaled Depth of Burrial	B	0.019737	$m/Kg^{1/3}$		
Site Constant	k	5000			
Site Exponent	e	1.6			

Results

SPL_{peak}	114	dBL		

Calculation based on Linehan and Wiss formula for calculation of air-overpressure

PPV	4	mm/s	0.15748	in/sec

Calculation based on USBM Bulletin 656 formula for calculation of vibration levels

References

P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," AIME Transactions, vol. 272, 1982

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name:	Resolution Copper
Scope of Work:	Tailings Conveyor/Tunnel
Calculation:	Specified Slant Distance - Output Blast Load
Calculation Identidier:	Calc4.A

Blast Planning Table

Vibration limit 0.1884 **in/sec** 4.79 **mm/sec**

Distance - Tunnel to surface (ft)		Site Factors		Blast Loading (W) in kg TNTe
feet	metres	k	e	
200	60	5000	1.6	1
400	121	5000	1.6	2
600	182	5000	1.6	6
800	243	5000	1.6	10
1000	304	5000	1.6	16
1200	365	5000	1.6	22
1400	426	5000	1.6	31
1600	487	5000	1.6	40
1800	548	5000	1.6	51
2000	609	5000	1.6	63
2200	670	5000	1.6	76
2400	731	5000	1.6	90
2600	792	5000	1.6	106
2800	853	5000	1.6	123
3000	914	5000	1.6	141
3200	975	5000	1.6	160
3400	1036	5000	1.6	181
3600	1097	5000	1.6	203
3800	1158	5000	1.6	226
4000	1219	5000	1.6	250
4200	1280	5000	1.6	276
4400	1341	5000	1.6	303
4600	1402	5000	1.6	331
4800	1463	5000	1.6	361
5000	1524	5000	1.6	391

References

P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," AIME Transactions, vol. 272, 1982

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807

USBM Blasting Calculation Sheet

Project Name: Resolution Copper

Scope of Work: Tailings Conveyor/Tunnel

Calculation: Specified Slant Distance - Output Blast Load

Calculation Identidier: Calc4.B

Blast Planning Table

Vibration limit 0.5 **in/sec** 12.7 **mm/sec**

Distance - Tunnel to surface (ft)		Site Factors		Blast Loading (W) in kg TNTe
feet	metres	k	e	
200	60	5000	1.6	2
400	121	5000	1.6	8
600	182	5000	1.6	19
800	243	5000	1.6	34
1000	304	5000	1.6	53
1200	365	5000	1.6	76
1400	426	5000	1.6	103
1600	487	5000	1.6	135
1800	548	5000	1.6	171
2000	609	5000	1.6	211
2200	670	5000	1.6	256
2400	731	5000	1.6	305
2600	792	5000	1.6	358
2800	853	5000	1.6	415
3000	914	5000	1.6	476
3200	975	5000	1.6	542
3400	1036	5000	1.6	612
3600	1097	5000	1.6	686
3800	1158	5000	1.6	765
4000	1219	5000	1.6	847
4200	1280	5000	1.6	934
4400	1341	5000	1.6	1025
4600	1402	5000	1.6	1121
4800	1463	5000	1.6	1220
5000	1524	5000	1.6	1324

References

P. Linehan and J. F. Wiss, "Vibration and Air Blast Noise From Surface Coal Mine Blasting," AIME Transactions, vol. 272, 1982

R. Nicholls, C. F. Johnson and W. I. Duvall, "Bulletin 656 - Blasting Vibrations and Their Effect on Structures," U.S. Dept. of the Interior, Bureau of Mines, Washington, 1971

TC160807