

7.4. MINING

DST was contacted by Bennett to conduct a mining impact assessment related to the development of the proposed facility. A summary of the issue identified in the Approved Terms of Reference is presented here with regards to potential impacts. The entire report entitled, "Mining Impact Assessment" can be found in separate Appendix 9.

The assessment was conducted and prepared in compliance with the Approved Terms of Reference for the Environmental Assessment. The current section describes:

- Effects of mining activity beneath the proposed site.

The description of the existing mining environment is discussed in Section 4.5.

7.4.1. *Impact of Ground Vibrations on Plant Facility - From Blasting*

Because of the inhomogeneous (mixed in type) nature of rock, it is impossible to make a reliable hypothetical prediction of the rate of ground motion reduction to be expected at a locality. A ground motion-monitoring program would be required to determine the practical allowances for the effect of local rock characteristics on ground motion. Such a study is beyond the scope of this report. The mining impact report discusses and applies criteria that have been established to minimize the effects of blasting vibrations on surface structures, to mining scenarios for the AK zone.

Considerable research has been done on the effects of drill hole blasting on surface structures. Conclusions of this research can be found in the more detailed Mining Impact Assessment, separate Volume 9.

When the results of various researchers are reduced to a common denominator, it has generally been established that a peak level of ground motion of less than 2 inches per second (in/sec) will result in a low probability of structural damage to residential dwellings. Canmet¹ established that a peak particle velocity of 2 in/sec would result in plaster cracking in a house, 8 in/sec will crack concrete blocks in a new home, 40 in/sec would result in misaligned shafts of mechanical equipment, pumps and compressors, and 60 in/sec would result in cracked concrete pads and structural damage to prefabricated metal buildings on concrete pads. The Blasters' Handbook, published by E. I. Du Pont de Nemours & Co. (Inc.), printed the following table on blast vibration:

Table 7-28 Blasters, Handbook (Vibration & Air Blast)

Peak Particle Velocity	Nature of Damage
2.0 in/sec	Safe blasting criterion for residential structures recommended by U. S. Bureau of Mines
2.8 – 3.3 in/sec	Threshold of damage from close-in blasting
5.4 in/sec	50% Probability of minor plaster damage
7.6 in/sec	50% Probability of major plaster damage
12 in/sec	Fall of rocks in unlined tunnels

¹ Bauer and Calder

The United States Office of Surface Mining (OSM) has issued regulations to surface coal mining operations controlling blasting effects. In this federal regulation, operators are given a choice of employing three methods to satisfy the regulation. Two of the methods require seismograph monitoring whereas the third method requires the operator to design blasts in accordance with the following table, which specifies a scaled distance design factor for use with various distances from the blast site:

Table 7-29 Maximum Permitted Particle Velocities at Various Distances from a Blast Site²

Distance from blast site (ft)	Maximum allowable peak particle velocity (in./sec.)
0 to 300	1.25
301 to 5,000	1.00
5,001 and beyond	0.75

The mining impact report compares the blasting affects of various mining scenarios to the Bennett plant by using the above mining regulation. Blast charge weights were calculated for each size of drill hole used in the different mining scenarios. Since it is possible for two holes to fire instantaneously, blast charge weights used to determine blasting affects on the plant were doubled for each size of drill hole. The above mining regulation was designed to protect homes from the effects of blasting. Since the design and construction of industrial plants is much more tough than homes, use of this regulation leads to conservative conclusions on the affects of blasting on the Bennett plant.

The surface outcrop of the first zone of higher-grade values is located as close as 77 metres (253 ft) to the northeast of the plant. Any underground mining of this zone would likely employ either the shrinkage mining method (described in Section x.x) or a narrow vein Alimak method, developed by raises from a ramp below the zone. Maximum blast charge weights, using these mining methods are 5.3 pounds of explosive (1¼ inch diameter holes with a maximum charge length of 10 feet). Using a charge weight of 10.6 pounds per blast hole, the safe distance equation shows that the minimum distance to the plant from the blast site to be 163 feet (50 metres). Since the plant is located more than 250 ft away, mining of this zone will have little affect the plant building.

The second zone of higher-grade values is located approximately 273 metres (897 ft) from the plant. Any surface mining of this zone will likely be by a narrow open cut method. Since the OSM calculated safe mining distance of 3 -inch diameter holes, 15 ft long (57.4 pounds per hole x 2 holes = 115 pounds) is 589 feet (~180 metres); mining of this zone will have little affect on the plant building. Using 3-inch diameter blast holes the calculated air blast from surface blasting in this zone will result in a calculated noise reading of approximately 123 decibels. This sound level is below the 136-decibel interim limit that was established by the U. S. Bureau of Mines for allowable air blasts. It will not result in any damage to the Bennett plant.

In accessing the AK zone from a surface ramp by means of mechanized drill jumbos, expected charge weights in the development blast holes (1½ inch diameter holes, 12 feet long) are 9.2 pounds of explosives per blast hole. Using a charge weight of 18.4 pounds per blast hole, the safe distance equation shows that the minimum distance to the plant from the blast site to be 236 feet (72 metres). The ramp should remain at least 72 metres away from the plant to ensure that no damage will result from mine

² United States Office of Surface Mining

development blasting. In reviewing likely locations for a surface ramp it appears that the ramp will remain at least 100 metres from the location of the Bennett plant.

Any mining from the surface ramp would likely employ the shrinkage mining method. The calculated safe mining distance of the shrinkage stoping method, using the OSM regulation, is 163 ft (50 metres). Other than a zone of higher-grade values located more than 77 metres north of the Bennett plant, diamond drilling to date has not revealed the presence of any other higher-grade zone that is closer than 273 m (897 ft) to the plant.

Any future large-scale mining of the AK zone will likely begin 300 metres below surface where mineable widths begin to show in the mineralized zone. If the zone were amenable to open stoping methods, sublevels would likely be developed at a maximum vertical spacing of 70 ft within the zone to be mined. From the sublevels, production drilling would likely be done by either vertical benching from an over cut, or ring drilling from drifts driven within the ore zone. Using this sublevel spacing, the maximum expected blast charge weights would be 210.5 pounds per delay for 55-foot long 3-inch diameter blast holes.

Given the mining widths discovered in the diamond drilling to date, it is much more likely that any future mining method would employ the shrinkage mining method. Using this method air leg drills would drill either horizontal or vertical holes that would result in charge weights of less than 6 pounds of explosive.

In assessing the possible effects of blast vibrations on the Bennett plant a very conservative assumption would be to use the higher 210.5-pound blast charge weight that would result from sublevel open stoping. Using the criteria established by OSM, the safe distance equation shows the minimum distance to the plant from the blast site for this charge weight is 798 feet. Since this distance is less than the approximate 308 metres (+1000ft) depth of the zone, blasting vibrations from underground mining employing one blast hole per delay with this charge weight will have little effect on the Bennett plant.

If two holes were blasted using the same delay (421 pounds per delay) the minimum distance to the plant from the blast site increases to 1,129 feet. This number shows that the blast velocity using this charge weight will exceed the OSM particle velocity criteria of 1 in/sec. Using the 421 pound charge weight and the distance from the plant, a scaled distance of this blast is calculated to be 49.3. Plotting this amount on the graph of scaled distance vs. peak particle velocity and using the limit line established by the United States Bureau of Mines illustrates that the resulting peak particle velocity of this blast would be less than two inches per second. Since the calculated peak particle velocity is less than 2 in/sec it is below the threshold of damage from close-in blasting (Table 7-29). It will not cause any damage to the proposed structure and installed equipment nor will it cause any disruption to the plant operation.

7.4.2. *Impacts to Groundwater*

A&A Environmental Services Inc. carried out a report entitled “Surface and Groundwater Impact Assessment, Description of Environment Affected”. This report provides an assessment of local groundwater and surface water conditions at the location of the proposed facility. For the groundwater assessment, the investigation focused on the unconsolidated soils and the upper 10 metres of the bedrock. A permanent groundwater-monitoring network is to be installed at the site and a sampling program implemented; the specifics of which are detailed in Section 7.2.7.2.

The impact of mining at a depth of 300 metres on the shallow groundwater flow system of the area is difficult to assess with the available information. De-watering for mining of the mineralized zone or of the associated underground workings could impact on the shallow groundwater, and will depend on the hydraulic connection between the surface and the depth of de-watering through fractures in the rocks.

7.4.3. Risk of Subsidence as a Result of Dewatering

It is well known that flowing water, with extremely high water velocities, is capable of moving significant amounts and sizes of rock and soil materials. However, velocities of 277 m/yr and hydraulic gradients due to mine dewatering, in which water flows downward under gravity in response to water being pumped out as the mine heading advances ever deeper, are minimal and would not impact soil or rock stability. Since the Bennett plant will be constructed on bedrock (massive volcanics) the impact of dewatering on the submerged weight of the overburden and bedrock will be negligible. Examination of diamond drill hole logs on holes completed in the vicinity of the plant location and examination of the drill core from two diamond drill holes that are located immediately behind the proposed location of the plant, confirm that the rock immediately beneath the site is a very competent volcanic rock. Competent massive volcanic rocks are not affected by the fluid mechanics of dewatering. It is concluded that there will be no risk of subsidence as a result of mine dewatering activities.

Should any foundations be supported on soil, the effects of dewatering must be allowed for in the Geotechnical design.

7.4.4. Effects of Ground Loading on the Site

Visual inspection of the first 75 feet of diamond drill hole AK-93-50 and the first 60 feet of diamond drill hole AK-93-51, both drilled from locations behind the Bennett plant location and examination of the drill logs, confirms that except for the first 10 feet in diamond drill hole AK-93-51, the rock in the vicinity below the plant is very competent (see photos in Appendix 9).

Floor loads range from a low of 1.8 metric tonnes per square metre (mt/sq m) at the shredder to a high of 30.4 mt/sq m at the west kiln support pad. Add to this the slab load in the process area of 1.6 mt/sq m and the maximum loading expected is in the order of 32 mt/sq m. Floor loads from the plant will be supported directly by the competent volcanic rock beneath the building foundation. Since the volcanic rock has a density of approximately 2.7, the weight of the volcanic rock beneath the building is approximately 2.7 metric tonnes per cubic metre. The AK zone is located approximately 300 metres below the plant. At this depth the load, from rock alone is 810-mt/sq m. The addition of the maximum load weight of 32-mt/sq m is expressed as a percentage addition of only 4 percent. It is concluded that the heaviest loading in the plant will have no measurable effect on the foundation rock below the plant.

7.4.5. Risk of Subsidence as a result of Crown Pillar Failure

Rock Quality Designation (RQD) is an indirect measure of the number of fractures and the amount of softening or alteration in a rock mass. It is obtained from drill cores by summing up the length of core recovered, counting only those pieces of sound core that are 100mm or more in length. The RQD value is expressed as a percentage and is the ratio of the summed core lengths to the total core length. An RQD value of less than 25 is rated as very poor quality, 25-50 is rated as poor quality, 50-75 is fair quality, 75-90 is good quality and 90-100 is excellent quality.

A summary of the diamond drill log for hole number AK-95-65, a 810 metre long drill hole located 270 metres east of the proposed plant is as follows:

Table 7-30 Drill Log: AK-95-65

Section	RQD (%)	Rock Description
2.8-62.0	80	Fine to medium grained greywacke
62.0-96.5	70	Greywacke
96.5 – 147.0	80	Greywacke
147.0-157.8	75	Hematitic lapilli tuff
157.8 – 167.2	50	Trachytic lapilli tuff
167.2 – 168.4	75	Trachytic lapilli tuff
168.4 – 168.7		Syenite porphyry
168-7 – 180.8	85	Heterolithic lapilli tuff

In summary only two zones of approximately 44 metres in length located between sections 62 - 96.5 and 157.8-167.2 metres from surface can be classified as fair (50-75) rock quality. Four zones totaling 149.8 metres are classified as good (75-90) rock quality and fourteen zones totaling 370 metres are classified as excellent (90-100) rock quality. Three zones totaling 218 metres were not classified for rock quality. In conclusion, more than seventy percent of the diamond drill core is classified as good and excellent rock quality, with less than 6 percent classified as fair rock quality (approximately 27 percent of the core was not classified).

Since other diamond drill hole logs available for the study did not describe the RQD for the encountered zones, the rock strengths shown above are likely typical for the zones encountered in both drill holes AK-95-50 and AK-95-51 which were drilled from an area that is immediately south of the Bennett plant location. This conclusion was verified in an inspection of the drill logs for both holes (see core logs in appendix) and in a brief inspection of the core from these two holes (refer to Photos 1-5 in Appendix 9).

Visual inspection of the photos taken of the main zone cut by diamond drill holes AK-93-48 and AK-93-51 indicate that the rock in the main zone is very competent (refer to Photos 1-5 in appendix A of Appendix 9).

Mine operators backfill open stopes to prevent an unraveling of ground conditions in a mine. If the ore zone can be safely mined without using fill and the ground conditions in the mine remain stable, the mine operator may elect to not use backfill in order to reduce mining costs.

Mining below the 300-metre level may utilize long hole open stoping mining methods. The main zone at this elevation is approximately 100 metres high. Diamond drill hole AK-93-48 encountered higher-grade gold values across a series of quartz veins that have the potential to be mined over a width of approximately 12 metres. Any remaining voids in the mine following mining, unless they are backfilled, have the potential to affect volumes that are twice the size of the original void before caving material completely fills the resulting larger void.

Ground conditions in a mine are generally governed by geology (rock strengths and structural conditions) and ground stress. Ground stresses at a depth of 300 metres below surface cannot be determined unless

they are measured. However, at a depth of 300 metres, in the Kirkland Lake camp, rock stress was never a concern. Examination of the photographs of the drill core at this elevation does not show any effects of ground stress. With the absence of stress, caving above a large open stope in a mine is governed by geology and driven by gravity. Given that a void in a mine has the potential to expand to twice the size of its original volume, a stope on the 450-metre level that is 150 metres high has the potential to cave to surface. The resulting caving front above a stope may be narrower or wider than the mined out stope. If the caving front is half the width of the original stope it has the potential to cave vertically for twice its height. In our example, a large stope on the 300-metre level that is 100 metres high that develops a caving front that is one-half the stope width has the potential to cave to surface.

Diamond drilling to date in the AK zone has not discovered the presence of vertical zones of weaker rock that would have the potential to influence the direction of retreat above any open stopes. Diamond drilling to date, as shown in the log of hole number AK-95-65, has discovered very competent rocks that would have the tendency to cave to a stable arch above any open stopes. The resulting stable arch may remain above the stope indefinitely and may never develop into a vertical caving front. Given the very competent nature of the rock in and above the AK main zone, the relatively narrow width of the average drill intersection, the fact that the plant is located more than 70 metres to the south of the zone projected to surface and the almost certain probability that any large open stoping method will use some degree of backfill, it is highly unlikely that any possible caving from open stopes on or below the 300-metre level will ever affect the plant location during the foreseeable future.

Diamond drilling to date has shown that any mining of the gold zone above the 300-metre level will likely be conducted using narrow (1.5 metre wide) mining methods. The mine operator may elect to not backfill these stopes but instead decide to leave them open. Due to the competent nature of the rocks in these narrow zones it is highly unlikely that these stopes would ever develop a vertical caving front that would impact surface.

7.4.6. Mitigation Measures and Net Effects

Visual inspection of available photos of the main zone cut by diamond drill holes AK-93-48 and AK-93-51 indicate that the rock in the main zone is very competent (refer to Photos 1-5 in Appendix A of Appendix 9).

A summary of the diamond drill log for hole number AK-95-65, a 810 metre long drill hole located 270 metres east of the proposed plant, concluded that more than seventy percent of the diamond drill core is classified as good and excellent rock quality, with less than 6 percent classified as fair rock quality (approximately 27 percent of the core was not classified). Since other diamond drill hole logs available for the study did not describe the RQD for the encountered zones, the rock strengths shown in hole number AK-95-65 are likely typical for the zones encountered in both drill holes AK-95-50 and AK-95-51 which were drilled from an area that is immediately south of the Bennett plant location. This conclusion was verified in an inspection of the drill logs for both holes and in a brief inspection of the core from these two holes.

Diamond drilling to date has shown that any mining of the gold zone above the 300-metre level will likely be conducted using narrow (1.5 metre wide) mining methods. Due to the competent nature of the rocks in these narrow zones it is highly unlikely that these stopes would ever develop a vertical caving front that would impact surface.

Given the very competent nature of the rock in and above the AK main zone, the relatively narrow width of the average drill intersection, the fact that the plant is located more than 70 metres to the south of the zone projected to surface and the almost certain probability that any large open stoping method will use some degree of backfill, it is highly unlikely that any possible caving from open stopes on or below the 300-metre level will ever affect the plant location during the foreseeable future.

Reported ground water flow (velocities of 277 m/yr) and expected hydraulic gradients due to mine dewatering are minimal and are not expected to impact soil or rock stability in the vicinity of the proposed Bennett plant. Since the Bennett plant will be constructed on bedrock (massive volcanics) it will not be subject to the possibility of subsidence as a result of mine dewatering activities.

Since any surface ramp will likely remain at least 100 metres away from the plant, blast vibrations from mine development will have little or no impact on the proposed Bennett plant. Mining the zone of identified higher-grade values, located 77 metres to the northeast of the plant mining of this zone will have little affect on the Bennett plant building. Blast vibrations from shrinkage mining of the narrow zones above and below the 300 metre level will have little or no affect on the proposed Bennett plant. In the unlikely event that long hole mining is used to mine the wider zones identified below the 300 metre level, blast vibrations from mining will be below 2 in/sec., the threshold of damage from close-in blasting and will not cause any damage to the plant and installed equipment nor will it cause any disruption to the Bennett operation.

Blast vibrations from surface mining the possible higher grade zone located 273 metres east of the plant will be below the threshold of damage from close-in blasting and will not result in any damage to the Bennett plant. The calculated air blast from surface blasting, using 3-inch diameter blast holes, will result in a sound level of 124 decibels, well below the 136-decibel interim limit that was established by the U. S. Bureau of Mines for allowable air blasts. It will not result in any damage to the Bennett plant.

Following a review of the active and dead loads in the plant it was concluded that the heaviest loading in the plant would have no measurable effect on the foundation bedrock below the plant.

7.4.7. Conclusion

In conclusion, no impact on operation of the high temperature incinerator is expected from future mining of the AK zone when considering ground stability and control, seismic effects of blasting and the effects of mine dewatering.

The consultant in mediating between the Ministry of Northern Development and Mines and Queenston has made recommendations. Both parties provided comment on the draft Environmental Assessment report and have resulted in recommendations including:

- Bennett meet with the holder of the mining rights to negotiate an agreement to allow defined mining exploration work to be conducted on facility property.
- Bennett takes the lead informing a liaison committee with the mining company that develops the Amalgamated Kirkland deposit. Suitable topics for discussion within the committee would be

topics of mutual concern including but not limited to mining plans including blasting methods, local traffic concerns, environmental concerns, etc.

- Should any facility foundations be supported on soil, the effects of dewatering must be allowed for in the Geotechnical design.
- Bennett has agreed to these recommendations and they are confirmed in Section 15.0 Summary of Commitments.

As demonstrated above the Mining Impact Assessment was completed pursuant to the approved Terms of Reference describing: effects on any areas known to be subject to physical hazards such as areas of erosion and slope instability; negative impacts to soil regimes; and effects of mining activity beneath the proposed site For the further detail on Mining Impacts please see Appendix 9, Mining Impact Assessment.