REMEDIATION AND CLOSURE METHODS

Remediation and closure methods available to secure the various types of abandoned mine openings typically found in Nova Scotia are outlined in Table 1. Details on each of these various closure options are provided in the following sections.

Table 1: Mine Openings Remediation Options

Nature of Abandoned Mine Opening	Closure Type	Method	Application	Effective Life
Vertical or Near Vertical Openings Vertical Shafts Inclined Shafts Raises	Warning	Sign	Warn and Alert	Temporary
	Barrier	Fence	Limit Access	Temporary
	Barricade	Steel Wire Screen	Restrict Access	Temporary
		Steel Grate	Restrict Access	Temporary
	Cap	Pre-Cast Concrete	Prevent Access	Long Term
		Cast-In-Place Concrete	Prevent Access	Long Term
		Monolithic Concrete Cap	Prevent Access	Long Term
	Seal	Backfilling	Prevent Access	Permanent
Horizontal or Near Horizontal Openings Adits Declines Slopes	Warning	Sign	Warn and Alert	Temporary
	Barrier	Fence	Limit Access	Temporary
	Barricade	Timber	Limit Access	Temporary
		Steel Wire Screen	Restrict Access	Temporary
		Steel Grate	Restrict Access	Temporary
		Rock or Concrete Wall	Prevent Access	Long term
	Seal	Blast Closure	Prevent Access	Permanent
		Backfilling	Prevent Access	Permanent
Subsidence or Caving Feature	Warning	Sign	Warn and Alert	Temporary
	Barrier	Fence	Limit Access	Temporary
	Seal	Backfilling	Prevent Access	Permanent

SIGN POSTING

Properly positioned signs can alert travellers to potential hazards in the area. Warning signs for open holes and other unsecured mine openings are available to private landowners from the Nova Scotia Department of Natural Resources.

Application

Because signs do not secure an open hole or abandoned mine opening, they should be used only as a minimum method to warn of low-risk hazards or as a temporary warning until an abandoned mine opening is secured.

Effective Placement of Warning Signs

To be effective, signs must be visible and noticed by all individuals travelling near an abandoned mine opening. To ensure this:

- Signs should be posted around the perimeter of the hazardous area as necessary to ensure a sign is visible to everyone approaching the area from every accessible route.

- Signs should be attached at "eye level" height, on a mature tree, sturdy post or stable structure located near the hazard.

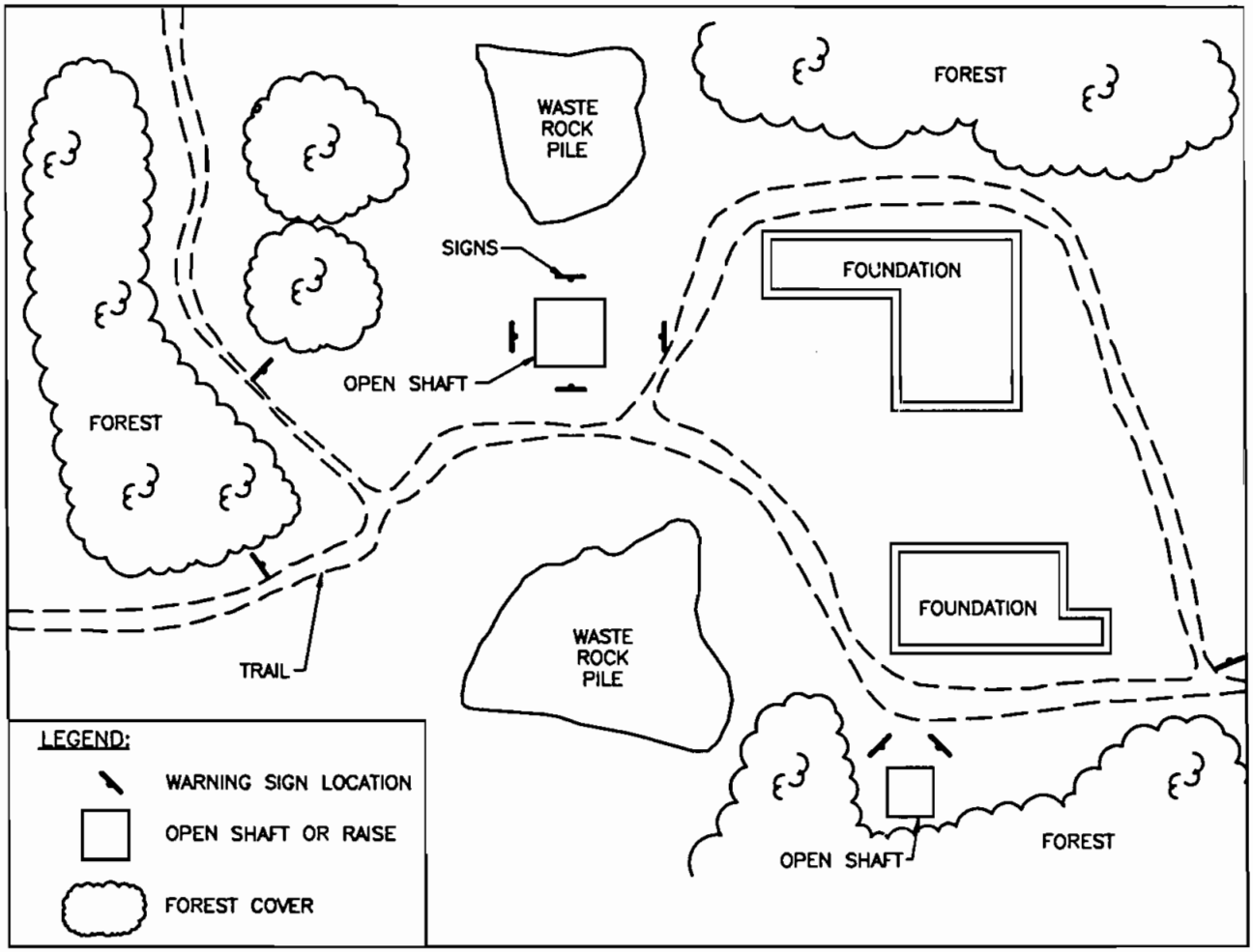
- Signs should be attached with galvanized nails, screws or wire, to reduce rusting of the fastener and the resulting loss of the sign. Galvanized washers can also be used to add support and to reduce breakage around any fastening holes in the sign.

- Brush and undergrowth which could obstruct the sign should be cleared away or trimmed.

General detail on the recommended placement of signs around an abandoned mine opening is shown in Figure 14.

Life Expectancy

A well-attached sign on a stable support should have a life expectancy of 5 to 10 years. Regular inspection and maintenance should extend the useful life and ensure signs are still posted.



Recommended placement of warning signs
Figure 14

Advantages

- Signs are inexpensive and are available from the local Nova Scotia Department of Natural Resources office.

- Signs are easy to install and can be attached to tress, posts and/or any stable structure located on, or in the immediate vicinity of the hazard.

- Signs can be placed in numerous locations to warn people approaching the hazard from any given direction.

Disadvantages

- Signs are only temporary in nature and require constant inspection by the land owner. They can be removed and vandalized or blown off by high winds. Vegetation and undergrowth can obstruct signs over time. Collapse of the support (tree, post or building) and rusting of the fastener can also result in the loss of the sign.

- Signs can often attract attention and draw curious individuals to an unsecured mine opening.

- Young children, foreign visitors and non-English speaking people who cannot read or understand the significance of the signs, may not be aware of the hazards.

Technical Details: See Appendix B - Section B-1

FENCING

Fencing, used in conjunction with warning signs, offers a method to outline the perimeter of a hazardous area. Fences will discourage access, but do not seal the opening and restrict entry.

Application

Fences can be used to outline the perimeter of a shaft, raise or subsidence area, or placed across the portal of an adit, decline or slope to restrict access. Because fences require regular inspection and maintenance, they are considered a temporary closure method.

Types

The most effective type of fencing is a galvanized chain link fence. Strands of barbed wire along the top of the fence will discourage climbing into the enclosed area. The fence height can vary with the location and severity of the hazard. Other suitable types of fences include:

- plastic snow or construction fencing;
- barbed wire;
- agricultural style; and
- wooden.

Effective Placement of Fencing

Where materials can be transported to the site, chain link fencing should be erected using galvanized metal posts and rails. Posts should be anchored in concrete or installed in a hole drilled in competent rock. Chain link fencing should not be attached to wooden structures or trees which could collapse or fall. In isolated, vehicle inaccessible areas, a temporary plastic or barbed wire fence attached to trees or wooden posts will provide a limited barrier around an abandoned mine opening.

Fencing should be installed a safe distance away from the perimeter of a shaft or vertical mine opening. As a general guideline, where the shaft collar is unstable and subject to subsidence and caving, fencing should be installed a distance of five times the largest dimension of the shaft. A general arrangement for fencing around a stable open shaft is shown on Figure 15.

Life Expectancy

The estimated life of a galvanized chain link fence is 10 to 15 years. With regular inspection and maintenance this can be increased.

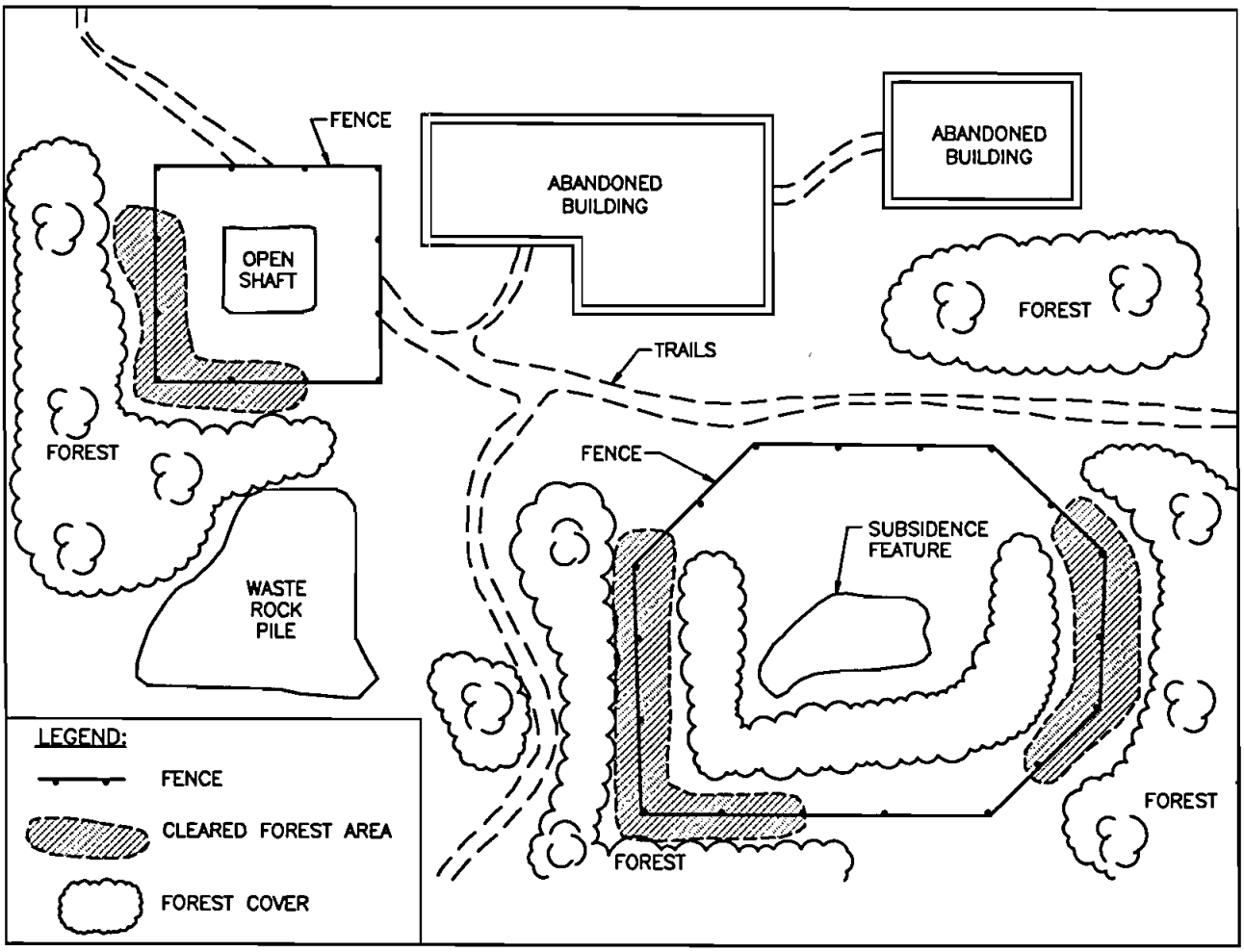
Advantages

- Fencing is relatively inexpensive and simple to install.
- Fencing provides a perimeter barrier and prevents accidental entry into hazardous areas.

Disadvantages

- Fencing offers only temporary protection and requires regular inspection and maintenance.
- Damage to fencing can occur from falling trees, subsidence of mine workings, vandalism, theft and corrosion.

Technical Details: See Appendix B - Section B-2



General fencing arrangements
Figure 15

STEEL WIRE SCREEN

Steel wire screening placed across an abandoned mine opening restricts unauthorized entry, while still providing limited access for small wildlife. Entry into the mine opening for mineral exploration or historical purposes is possible by removing the barrier.

Types

Commercially available wire mesh screening, commonly used as concrete reinforcing, is suitable.

Application

Steel wire screen barricades are suitable for both rectangular or odd shaped openings, including shafts and adits. This method is considered a temporary closure method.

Installation

Vertical Shafts, Inclined Shafts and Raises

Proper installation requires that the steel wire screen be firmly anchored to competent bedrock or a stable concrete shaft collar. This may require the removal of till or soil around the opening to expose the bedrock or concrete collar. The steel screening is then positioned over the opening and anchored using rock bolts or grouted rebar pins. Concrete expansion anchors can also be used to attach the steel screen to a concrete shaft collar. Following installation, the steel screening and any other bare steel rock bolts or pins should be covered with a zinc-rich protective paint.

Adits, Declines and Slopes

Prior to installation, any loose rock above and beside the entrance, or on the roof and walls of the opening, must be removed or supported. Install the steel screen over the entrance or inside the opening using rock bolts or grouted rebar pins. Following installation, any bare steel should be covered with a zinc-rich protective paint.

Life Expectancy

Without regular maintenance and repairs, the estimated life expectancy of a steel wire screen closure is 10 to 15 years.

Advantages

- Steel wire screen barricades restrict accidental or intentional entry; however, permit natural airflow and access to mine openings for wildlife.

- Steel wire barricades are relatively inexpensive and can be fabricated off-site and transported into the field for installation.

- Wire screen barricades are easy to install and can be installed inside the mine opening to reduce the visibility of the closure method.

Disadvantages

- Steel wire screen barricades are subject to vandalism and corrosion and require regular maintenance and inspection.

- Installation may require that rock around the entrance or inside the mine opening be chipped and/or trimmed to permit attachment of the wire screen.

- Installation generally requires a compressor to power a rock drill for drilling and installation of rock bolt or rebar anchor pins, which can limit installation in remote or vehicle inaccessible locations.

Technical Details: See Appendix B - Section B-3

STEEL GRATE CLOSURES

Steel grate closure methods restrict entry into abandoned mine openings while still providing access for small wildlife and airflow. Entry into the mine opening for mineral exploration or historical purposes is possible by removing the barrier.

Types

Steel grate barricades can be fabricated from angle iron, rebar or commercially available floor grating, attached to a rigid steel frame.

Application

Steel grate closure methods are suitable for both rectangular or odd shaped openings. Steel grate closures are typically interchangeable with wire screening; however, steel grates offer increased security and durability. This method is considered as a temporary closure method.

Installation

Vertical Shafts, Inclined Shafts and Raises

Proper installation requires that steel grates be firmly anchored to competent bedrock or a stable concrete shaft collar. This may require the removal of till or soil around the opening to expose bedrock or a concrete shaft collar. It may also be necessary to chip or trim around the installation area to minimize gaps and ensure uniform contact between the steel frame and the bedrock or shaft collar.

The steel grate is positioned over the opening and anchored to the bedrock or concrete shaft collar using rock bolts or grouted rebar pins or anchored into a cast-in-place concrete collar positioned around the perimeter of the existing shaft collar or raise opening. Concrete expansion anchors and pre-fabricated brackets can also be used to attach the steel grate to the top of a concrete shaft collar. Following installation, any bare steel should be covered with a zinc-rich protective paint.

Adits, Declines and Slopes

Prior to installation, any loose rock above and beside the adit entrance or on the roof and walls of the adit must be scaled down or supported. Chip or trim rock around the installation area as required to minimize gaps and ensure uniform contact between the steel frame and the rock face or perimeter of the adit, decline or slope. Install the steel grate over the entrance or inside the opening, using rock bolts or grouted rebar pins. Following installation, any bare steel should be covered with a zinc-rich protective paint.

Life Expectancy

Without regular maintenance and repair, the life expectancy of a steel grate is estimated at between 15 and 20 years.

Advantages

- Steel grate closure methods restrict accidental entry, yet permit airflow and access to mine openings for small wildlife.
- Steel grates are relatively inexpensive and can be fabricated off-site and transported into the field for installation.
- Steel grates are easy to install and can be installed inside the mine opening to reduce the visibility of the closure method.

Disadvantages

- Steel grate closure methods are subject to vandalism and corrosion and require regular maintenance.
- Steel grates must be custom fabricated for individual openings.
- Installation may require the rock around the entrance or inside the opening be chipped or trimmed to permit attachment of the steel grate frame.
- Installation generally requires a compressor to power a rock drill for drilling and installation of rock bolt or rebar anchor pins which can limit installation in remote or vehicle inaccessible locations.

Technical Details: See Appendix B - Section B-4

BULKHEAD CLOSURES

Bulkhead closures provide a secure seal which completely restricts access into an abandoned adit, decline or slope, where there is no requirement to provide access for wildlife or to retain natural airflow. Entry can still be gained into the mine opening for mineral exploration or historical purposes if required by demolition of the bulkhead or providing an access portal at the time of construction.

Types

Bulkheads can be constructed of native rock or concrete block.

Application

Bulkhead closure methods are used where there is a requirement to completely restrict access into an adit, decline or slope. Because of the secure nature of the construction, a rock or concrete block bulkhead is effective at preventing entry by the public and is generally resistant to damage from vandalism and corrosion. It is considered a long-term closure method.

Installation

At the selected bulkhead location, any loose rock around the perimeter of the opening, including the floor, should be removed to ensure a stable foundation. If the floor is uneven and a concrete block bulkhead is to be constructed, it may be necessary to level the floor with concrete or chip away the uneven rock to create a smooth, level foundation.

Using native rock or concrete block, construct the bulkhead, sealing as close as possible to the walls and roof. Any gaps between the walls and roof of the opening and the bulkhead should be sealed with concrete. A drainage pipe should be installed at the base of the bulkhead if water is noted draining from the mine opening.

Life Expectancy

Unless damaged by rock falls resulting from unstable conditions or vandalism, the estimated life of a native rock or concrete block bulkhead, is between 40 and 50 years.

Advantages

- Openings are completely sealed and public access is restricted.
- Closure is secure and generally resistant to vandalism and natural deterioration from weathering.

- Native rock may be locally available in sufficient quantities from adjacent waste rock piles.
- Native rock closure method is suitable for remote or trail accessible sites.
- Bulkheads can be installed inside the opening to reduce the visibility of the seal.

Disadvantages

- Construction of bulkheads is labour intensive.
- Unless native rock is available, concrete blocks must be transported to site which is expensive for remote, vehicle inaccessible locations.

Technical Details: See Appendix B - Section B-5

CONCRETE CAP CLOSURES

Concrete caps completely seal off an open shaft or raise, and permit reclamation and revegetation of the area over the mine opening.

Types

Effective closure method for vertical or near-vertical shafts and raises include pre-cast concrete panels, cast-in-place concrete caps and monolithic concrete caps.

Application

Concrete caps are suitable for vertical or near-vertical shafts and raises where there is a need to completely restrict access and secure the mine opening. The caps can, however, be removed if there is a requirement to access the mine opening at a later date.

A pre-cast or cast-in-place concrete cap must be designed for each site-specific shaft or raise and should be constructed only where the shaft collar or raise opening is in competent rock. They are suitable for square or rectangular openings, yet can be designed to seal any irregular shaped opening. Monolithic concrete caps are typically used to secure shaft or raise openings over which the surface soil or fill has begun to subside into the opening, although the mine opening is still covered and not visible.

In areas where acid drainage may be a concern, sulphate resistant cement should be used. Because of the potential for deterioration, concrete caps are considered a long-term closure method.

Installation

Pre-Cast Concrete Panels

Pre-cast concrete panels must be positioned on bedrock or a structurally sound, competent concrete shaft collar. Depending upon field conditions, it may be necessary to excavate to bedrock and/or remove any loose or weathered rock from around the shaft collar.

Once competent bedrock is exposed, a gravel levelling pad should be placed around the shaft opening onto which the pre-cast panels are positioned. If support beams are required, to support the pre-cast panels, they should be positioned in notches cut into the bedrock to maintain a level bearing surface for the pre-cast concrete panels. Support beams should also be set on a gravel base or embedded in a concrete levelling course cast-in-place onto the bedrock notches. Pre-cast concrete panels can also be placed directly on a competent concrete shaft collar.

Cast-In-Place Concrete Cap

A cast-in-place concrete cap can be installed over or in a vertical or near-vertical mine shaft or raise opening or directly on a structurally sound, competent concrete shaft collar. Depending upon field conditions, it may be necessary to excavate to bedrock and/or remove loose or weathered rock from around the mine opening.

If a competent concrete shaft collar is present, the cast-in-place concrete cap can be cast directly onto the top of the collar. The formwork should be built to extend a distance below the top of the collar to permit the new cast-in-place cap to be "keyed" into the existing shaft opening.

If a concrete shaft collar is not present, once competent bedrock is exposed around the opening, forms should be constructed around and over the opening using wood or stay-in-place galvanized metal formwork. Forms can also be installed within the shaft or raise opening if site conditions require. To assist with drainage, non-corrosive pipes can be installed through the concrete.

Following closure, caps constructed below grade on bedrock should be backfill with fill and revegetated. The fill should be contoured to establish a mound over the shaft cap with a gentle slope down to the original surface grade to provide drainage away from the shaft area.

Monolithic Concrete Cap

Monolithic concrete caps can be used as a closure method within a subsidence cone over a shaft or raise opening, where overlying soil or fill has begun caving into the opening, although the shaft or raise opening is not visible. Monolithic concrete caps are cast directly onto the bottom of the subsidence feature on the soil or fill, using the sides of the subsidence cone to contain the concrete. Depending upon field conditions, it may be necessary to enlarge the size and/or flatten the bottom of the subsidence feature over the mine opening, to create a slab which is larger in size than the shaft or raise opening.

The monolithic concrete cap must be larger than the size of the shaft or raise opening to both maintain a cap over voids created by continued subsidence of soil or fill into the mine opening and support backfill which may be placed on the monolithic concrete cap to fill the excavation.

Life Expectancy

Where a concrete cap has been properly installed over a shaft or raise opening, pre-cast concrete panels, a cast-in-place concrete cap or a monolithic concrete cap, should last 30 to 50 years. The installation should be monitored, however, as over time, the concrete will deteriorate, steel reinforcing will corrode and/or the mine openings may cave or subside.

Advantages

- The abandoned mine opening is completely sealed and the area can be revegetated.
- The closure method is secure and not susceptible to vandalism and/or damage.
- No maintenance is required; however, periodic inspections are recommended to check for subsidence of cover soil due to deterioration of concrete.

Disadvantages

- Heavy equipment is typically required for excavation and/or to place or cast concrete.
- Concrete caps can deteriorate over time, resulting in potential failure and subsidence of backfill.

Technical Details: See Appendix B - Section B-6

BLAST CLOSURES

Blast closures consist of sealing an adit, decline or slope by filling the opening with broken rock through the use of controlled blasting. The broken rock creates a permanent seal which completely restricts access into the abandoned mine opening and is generally resistant to damage from vandalism and natural deterioration through weathering.

All blasting activities must be conducted in compliance with Nova Scotia Department of the Environment and Nova Scotia Department of Labour, Occupational Health and Safety requirements.

Application

Blast closure methods are appropriate where there is a requirement to permanently restrict access into an adit or shallow inclined shaft, decline or slope and there is no requirement to provide access for wildlife or retain natural airflow. This method is considered a permanent closure method.

Method

Each site should be evaluated and an appropriate blasting plan prepared. Based on an approved blasting plan, blast holes are drilled above and around the entrance of the adit or inclined shaft. If conditions permit, blast holes should also be drilled inside the mine opening to ensure more complete closure.

Following blasting, conditions above and around the entrance to the opening must be inspected for loose rock. Any loose rock encountered must be removed or secured prior to abandonment of the site. It is recommended that the site be inspected 4 to 6 months after closure, to ensure the blasted rock has not settled, exposing the top of the opening. A drainage pipe should be installed prior to closure if water is noted draining from the mine opening.

Life Expectancy

Depending upon the nature of the rock, blast closure in a competent rock should provide a permanent seal. Openings sealed with less competent rocks such as shales, sandstones and other soft, friable sedimentary rocks which tend to degrade and erode, may over time result in settlement leading to partial exposure of the abandoned mine opening.

Advantages

- Openings are completely sealed to public access.
- Closure is secure and generally resistant to vandalism and natural deterioration.
- The method can be used to seal unstable openings where access is not possible.
- Broken rock at the entrance of the opening can be covered with soil and vegetated as required.

Disadvantages

- Drill(s) and compressors are required to drill blast holes.
- A licensed blaster is required and a safe, efficient blasting plan must be designed and approved by knowledgable person for each site.
- Blasting may not be possible or permitted near residential or commercial sites because of vibration and fly rock.
- Wildlife habitat and any historical resources associated with the mine opening are lost.
- The effectiveness of the method is reduced if unsafe conditions prohibit access into the opening to drill blast holes.

Technical Details: See Appendix B - Section B-7

BACKFILL CLOSURES

Backfill closures consist of completely sealing mine openings with on-site or imported fill. Normally, backfilling is carried out using heavy equipment (bulldozers or loaders); however, for small openings in isolated areas, filling can be done by hand.

Application

Backfilling closure methods are typically applicable for all types of abandoned mine openings where there is a requirement to completely seal the opening. Backfilling will prevent access for exploration or archaeological purposes and wildlife and block any natural airflow. Since this closure method may require entry into an abandoned opening, consultation with the Nova Scotia Department of Labour, Director of Mine Safety is required.

Materials

Recommended backfill material should consist of a well graded rock fill and coarse rip-rap. Overburden or native till may also be required for a cover soil to permit revegetation.

Preparation

Prior to backfilling a mine opening, any easily accessible wood, domestic refuse and other debris should be removed from within and around the opening as conditions permit, however, never enter an unsafe mine opening to remove any material. Support posts in adits, inclined shafts and slopes should never be removed no matter how deteriorated they appear. Removal of a support could result in a rock fall.

Procedure

Vertical Shafts, Inclined Shafts, Raises and Subsidence Features

Vertical shafts, inclined shafts, raises or subsidence features should be filled with a well graded rock fill. A coarse, graded rip-rap material should be placed in the bottom of the opening to a height which extends above the roof of any intersecting tunnel. In deep or water-filled openings, fill until the rip-rap is visible from the edge of the opening. The remainder of the opening should be backfilled with a graded rock fill. Waste rock from on-site or a similar rock from a local source is generally acceptable.

Following backfilling, cover the opening with native till or overburden and revegetate. The fill should be contoured to establish a mound over the shaft cap to allow for settlement. Establish a gentle slope down to the original surface grade.

Adits, Declines and Slopes

Adits, declines and slopes should be backfilled using a well graded rock fill intermixed with large boulders to discourage people from digging into the backfill. Where the end of the fill is planned, a bulkhead should be established across the mine opening. The bulkhead will provide a backstop against which the rock fill can be pushed. If drainage is required, a drainage pipe should be installed in the opening prior to the commencement of backfilling.

Backfill the opening using mechanical or manual methods, ensuring the rock fill is placed as close as possible to the top of the opening along the full length of the backfilled section. Once the opening is filled, extend the rock fill past the adit or incline shaft opening and mound the fill over the top of the entrance to completely seal the opening and compensate for settlement. The fill outside the entrance should be covered with either a coarse rip-rap to reduce erosion or a native till to permit vegetation.

Life Expectancy

Backfill consisting of a competent rock should provide a permanent seal. Openings sealed with less competent backfill such as shales, sandstones and other soft, friable sedimentary rocks which tend to degrade and erode may over time, may result in settlement leading to exposure of the abandoned opening.

Advantages

- Backfill provides a permanent seal which is generally resistant to vandalism and natural deterioration.
- Unless subsidence results in excessive settlement of the fill, backfilled openings require little to no maintenance.
- The backfilled area can be revegetated and restored.
- The backfill will provide some support to the abandoned opening which may help reduce or prevent additional caving or subsidence around the mine opening.

Disadvantages

- A backfilled opening results in the loss of wildlife habitat and any historical resources associated with the mine opening.

- A backfilled opening may require some maintenance over the short term due to settlement of the fill.

- The site must be vehicle accessible if other than small openings are to be filled.

Technical Details: See Appendix B - Section B-8