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February 12, 2021

Northdale Sanitary District Board of Trustees
c/o Toni Davila
tonidavila@aol.com

Re: South Dakota School of Mines and Technology student-generated report – Hideaway Hills Mine Mitigation

Dear Toni:

The South Dakota School of Mines and Technology student-generated report, "Hideaway Hills Mine Mitigation," is attached and provided for public dissemination for those requesting the same. The report is the product of a senior design project completed by students in the Mining Engineering Department of SDSM&T. The Board's sole involvement, at the request of the Mining Engineering Department, was to assist the institution and its students in furthering their education by serving as a hypothetical "client" in the student-led exercise. The project and report were for educational purposes only, as set forth in the Board's Resolution approving participation dated August 11, 2020 (attached). Neither the Board nor its members make any representations or warranties regarding the contents or accuracy of the report in any respect.

The attached report is as originally provided to the Board, with the exception that the names and contact information of the student authors have been redacted at the request of SDSM&T pursuant to the Family Educational Rights and Privacy Act (FERPA). Additionally, a notation was added to the third page of the report which is a hypothetical "invoice" from the students to confirm that this document was for illustrative purposes only – no actual compensation was requested or paid.

Sincerely,

Michael C. Loos

RESOLUTION RE SCHOOL OF MINES MINING ENGINEERING & MANAGEMENT 2020 SENIOR DESIGN PROJECT

Whereas the Board has been approached by representatives of South Dakota Mines Department of Mining Engineering and Management ("School") with regard to a proposed Senior Design Project involving the study of the Hideaway Mine ("Mine") as it relates to the surface subsidence in the Hideaway Hills Subdivision; and

Whereas the stated objective of the project is to "explore and evaluate potential mitigation measures" relating to the Mine. The complete Project Outline is attached hereto as Exhibit A. The project "does not include causation or responsibility for the subsidence." Instead, the goal is for the students, working with faculty and industry mentors, to "provide engineering alternatives designed to restore the subdivision/residential community on a sustainable basis, insuring high confidence for a safe future of the residences and ancillary infrastructure, with a minimum of continuing maintenance for a minimum of 50 years."; and

Whereas the District shall serve as the "industry contact" and hypothetical "client" to receive information and ultimately a final analysis completed by the student groups; and

Whereas the District shall provide access to public areas to participants and otherwise cooperate as appropriate; and

Whereas the District's participation shall not require any compensation or remuneration, nor shall the District receive any compensation for its participation; and

Whereas the School is an important resource for the community worthy of support; and

Whereas Senior Design Projects are an important part of the academic success of students in providing real-world engineering issues for study and analysis; and

Whereas the Project is meant for academic purposes only without warranties, the District and its members may nonetheless benefit from additional information provided by the work product of the Project.

Wherefore, it is:
RESOLVED that the District shall serve as the industry contact and hypothetical client for the 2020 Senior Design Project as set forth in the Project Outline, subject to final agreements memorialization of understanding between the District and School.

Northdale Sanitation District Board of Trustees

By: Toni Davila
President
Date: 8·11·2020

Hideaway Hills Mine Mitigation

[redacted]

Rapid Fill

Rapid City, SD

November 30th, 2020

Letter of Transmittal

Rapid Fill
Mining Engineering Department
South Dakota Mines
501 East Saint Joseph Street
Rapid City, SD 57701

November 30th, 2020

Toni Davila
Northdale Sanitary District
4924 Saratoga Drive
Black Hawk, SD 57718

Dear Ms. Davila,

It is Rapid Fill's pleasure to deliver the results of our consulting work on the Hideaway Hills Mine Mitigation consulting work.

This report examines different proposed mitigation measures to remedy the ground stability problems caused by old mine workings in the Hideaway Hills subdivision. This proposal includes a scope of work, design work, planning, economic analysis, and recommendation. Please note that this consultation was performed with a level of error of plus or minus fifty percent.

We hope you find this report informative and that it can guide future studies in solving the aforementioned problems. Thank you for your cooperation in this matter. Please feel free to contact us with any questions or concerns.

Sincerely,

The Rapid Fill Team:

[redacted]

RAPID FILL

FROM: Rapid Fill
501 E. St. Joseph St.
Rapid City, SD 57701
[redacted]

INVOICE NO. 12-31-2020-1
DATE 1-Dec-20
CUSTOMER ID SanDistONE

TO client: Northdale Sanitation district
Attn: Toni Davila
4924 Saratoga Dr
Black Hawk, SD 57718
tonidavila@aol.com

PERIOD:
August 23, 2020 - December 31-2020

Provider	JOB	PAYMENT TERMS	DUE DATE
	Hideaway Hills Consultation	Balance Due: net 30 days	12/31/20

DATE	QUANTITY / HOURS	DESCRIPTION	Hourly RATE	LINE TOTAL
8/23/2020 - 12/1/2020	134.75	Team Manager Billable Hours	$ 125.00	$ 16,843.75
8/23/2020 - 12/1/2020	438.00	Team Member Billable Hours	$ 100.00	$ 43,800.00
8/23/2020 - 12/1/2020	24.50	SDSM&T Faculty Billable Hours	$ 175.00	$ 4,287.50
8/23/2020 - 12/1/2020	5.00	Advisor Billable Hours	$ 175.00	$ 875.00
8/23/2020 - 12/1/2020	4.00	Client Non- Billable Hours	$ 150.00	$ 600.00

Note: For Illustration Purposes Only (Not an actual bill)

EXPENSES:

Travel	20	mileage	$ 0.75	$ 15.00
			SUBTOTAL	$ 66,421.25
			Minus Client Hours	$ 875.00

Delivered By: Mark Bowron

TOTAL BALANCE OWED: $ 65,546.25

1-Dec-20

Date

Signature:

Executive Summary

Rapid Fill was approached to propose several mitigation measures to handle the ground stability problems caused by old mine workings in the Hideaway Hills subdivision. Measures researched and designed included paste fill, underground working stabilization, house moving, reclamation and no action. Costs for these measures range from 1.5 million dollars to over 3 million dollars. Data was sourced from current industry practices and remediation of subsidence caused by old mine workings in the State of Wyoming. Mitigation measures were evaluated based on worker safety, upfront and recurring costs, the public perspective and the perpetuity of the solution.

Given these constraints, Rapid Fill recommends the mine reclamation measure be implemented, as it completely removes the void caused by the underground workings and is the most long-term solution.

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Introduction

Objective

The objective of this proposal is to investigate and compare mitigation techniques for the subsidence issues resulting from a residential subdivision being constructed over the Hideaway mine in Black Hawk SD. The subsidence occurred on the northern half of East Daisy Drive in the Hideaway Hills subdivision.

Scope

Engineering alternatives will be designed and evaluated at a scoping study level of error, in this case plus or minus 50%, to help mitigate the effects felt in the subdivision/ residential community, ensuring high confidence for a safe future of the residences and ancillary infrastructure, with continuing maintenance. A sequence of events will be evaluated from the 1900's to present day to advance the hypothesis of the events leading to the current status of the affected area.

Under this scope, Rapid Fill will develop and assess the feasibility of various mitigation techniques that will fulfill the stated objective of the engineering work.

Rapid Fill will not examine the responsibility related to the subsidence problem, as it is outside the scope of work.

Project Significance

This project has modern precedent because it will examine ways to mitigate the subsidence issues occurring in the residential subdivision and attempt to lessen the impacts felt by the community.

Background

Site Information

Legal description of property: Located in the East Half of the NW ¼ of Section 8, Township 2 Range 7, Meade County, South Dakota. The affected area is on the Western side of highway I-90, on the North-Eastern side of Daisy Drive. In the subdivision, fourteen homes have been evacuated for the safety of the residents.

Geology

Geologic Cross-section

The general strata of the area consists of a topmost layer of alluvium and terrace deposits, interspersed with sandstone, siltstone, and lower-class shales from the Redwater member. This layer averages a maximum thickness of 33ft.

The next layer is the northeast dipping Spearfish Formation, which consists of mudstone and siltstone with 18 to 28 feet thick gypsum beds and veins occurring throughout. This formation averages a thickness of 402-497 ft and is the projects main area of concern. Below is a general picture of the surface geology of the subdivision.

From well drilling logs, the lower geology consists of the following:

- Minnekahta Limestone/ Opeche Shale with a thickness of 43-60ft and 48-162ft, respectively.
- The Minnelusa Formation, with a thickness of 450-550ft.
- The Paha Sapa Limestone, with a thickness of 400-450ft

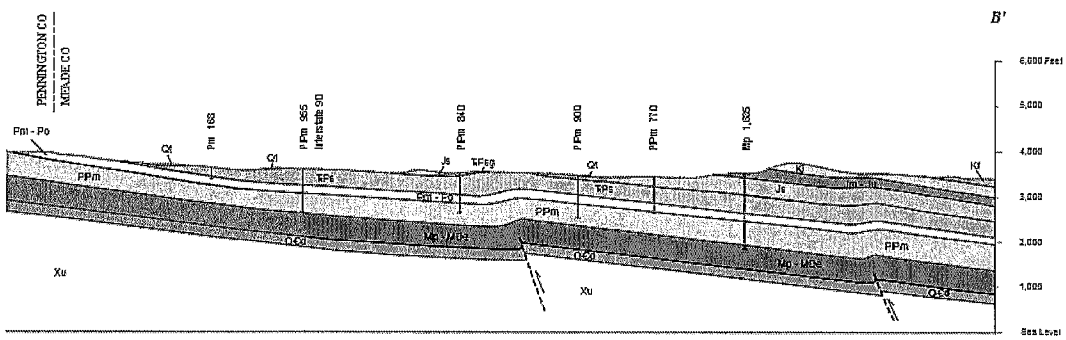

Figure 1: Geologic Cross-section

Groundwater

Water table data was acquired through the United States Geologic Survey for South Dakota. Seventeen points surrounding the mine were put into the Vulcan software to show the water tables relation to the depth of the mine. This was done to provide a visual for where the water level is in the mine void. There is a distance of 10 meters from the estimated average of the water table height to the lower portion of the void.

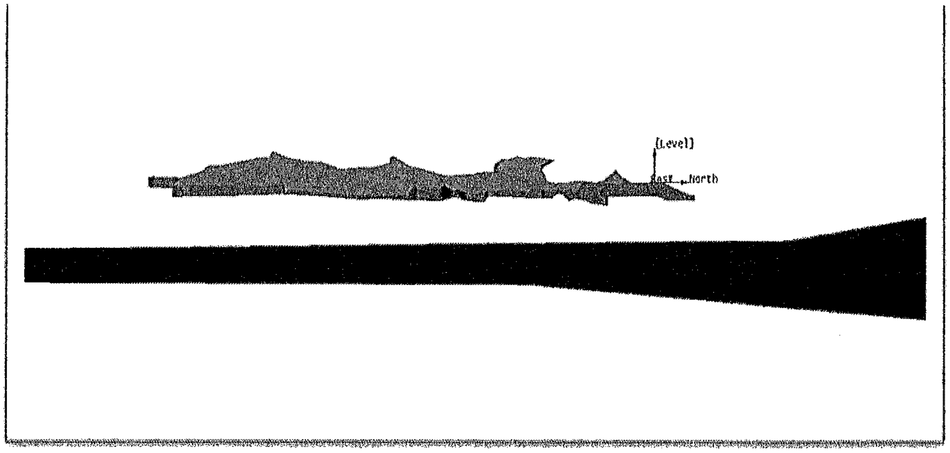

Figure 2: Vulcan Screen shot of estimated average water table height compared to mine void depth (East to West)

Rock Testing

Rock testing was limited due to the amount of available material from the mine sight. Factors of safety could not be accurately calculated from three samples. Triaxial tests were attempted on the samples with the intention of understanding the strength of the pillars in the mine. An empirical approach was taken with the information that was known. From the observations of the site visit, the gypsum samples were designated a rock mass rating (RMR) of 39. This scale is from 0 to 100 with 0 being very poor and 100 being very good. Table 22, in appendices 1, was used for classifying this RMR. The degradation of the pillars and roof of the mine correlate with the RMR.

Underground Workings

The underground workings were constructed using relative measurements from a traverse line and data provided from the Paha Sapa Grotto group. The workings are approximately 660ft long, and 216ft at the widest portion. The total volume of the underground workings is 29.9k cubic yards, not including the pillar volumes. The workings extend south and east through the Hideaway Hills subdivision but are hypothesized to not go beneath U.S. interstate I-90.

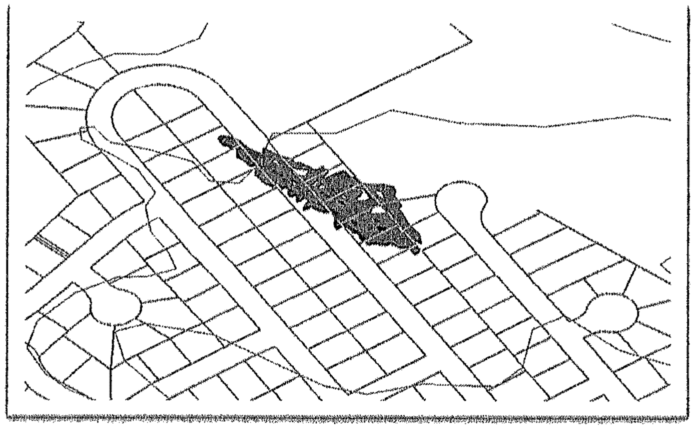

Figure 3: Underground Workings

The image above is a 3D generated model and its location relative to the topography, as well as the properties in the subdivision. The underground workings average a height of 10-11ft to the back; however, some sections go upwards of 15-16ft or intersect with the surface, causing the sinkholes.

Sequence of Events

The Dakota Plaster Company began mining the site in 1910. Gypsum that was exposed at the surface was mined using conventional quarrying methods until the dipping gypsum deposit required too much overburden removal to mine economically. Mining then progressed underground via several portals driven into the highwall. Underground mining used the room and pillar method. [63]

According to the South Dakota State Planning Board, work continued until 1930 when the site was purchased by the U.S. Gypsum Company. The U.S. Bureau of Mines lists the site is not operating in 1936, but that there was still potential to mine at the site in the future. The gypsum mine in the neighboring community of Piedmont was supplying enough gypsum for the area and the facilities at Black Hawk were subsequently dismantled. [63]

Aerial photos taken by the United States Forest Service in 1938 show the exposed highwall and the outlines of several buildings onsite. [64]

Figure 4: USFS air photo of site from 1938 - arrow points to highwall [64]

An aerial photo from 1952 shows that the highwall is less visible, indicating that the excavation has been filled. Also, of note is the lack of buildings and associated mining infrastructure. [25] Fill material consists of construction debris and fill dirt, as well as an automobile. It is hypothesized that the excavation was filled with trash and any nearby materials as it was used as an improvised landfill.

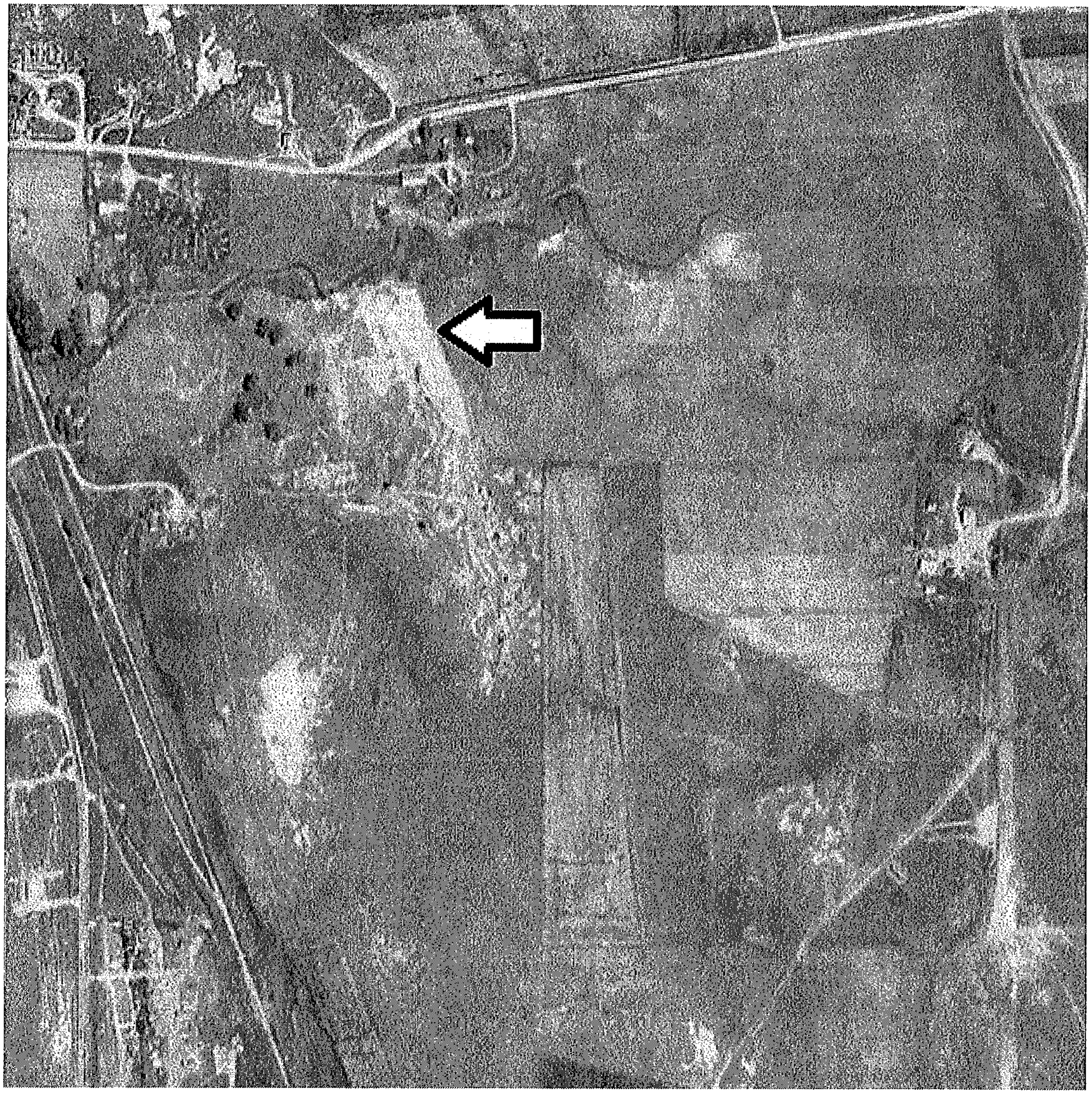

Figure 5: 1952 aerial photo of site – arrow points to former highwall location [25]

In the early 1970s US interstate I-90 was constructed through the area, and an aerial photo from 1971 shows the former mine site in relation to the highway. Aerials from 1982 show the community of Black Hawk growing around the area. Google Earth has imagery from 1998 to 2017. The 1998 imagery shows a faint outline of the highwall excavation, and an otherwise undisturbed site. [5]

Sequence of Events

The plan for the Hideaway Hills Subdivision was presented to the Mead County Planning Board in July of 2000. [46] In 2002 the Western half of the Hideaway Hills Subdivision was constructed, the Eastern half followed in 2004. Work began on the Hideaway Hills II subdivision in 2006, which consists of three cul-de-sacs to the South-East of Daisy Drive. [47] In 2006 the subdivision developer reported to the Mead County Planning Board that part of Daisy Drive was "caving into the old underground mine" and wished to close part of the street. The Planning Board stated that the road must be fixed correctly as the Board would not "approve the closing of Daisy Drive". [48] The hole in the road was filled in with gravel and paved over.

At 5:30 PM on April 27th, 2020 a sinkhole opened in the driveway of 7013 East Daisy Drive. Decades of weathering caused by water inflow caused the fill that had been placed against the highwall to erode into the underground workings via the portals along the highwall. Figure three shows the location of the highwall in relation to Daisy Drive.

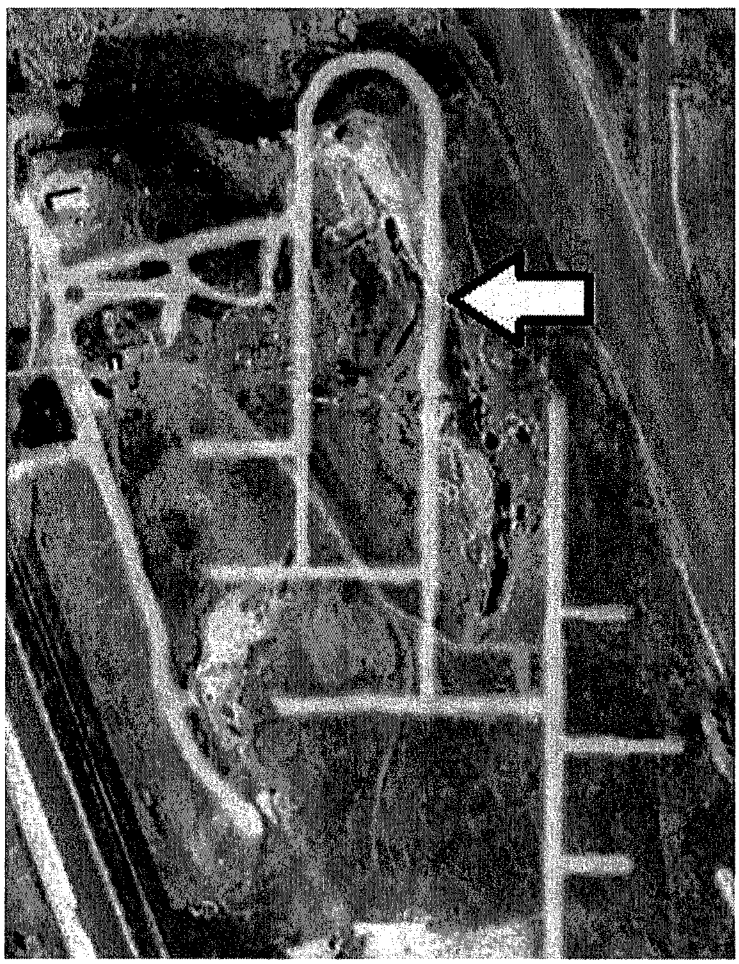

Figure 6: Composite Image of 1971 aerial photo and map of Black Hawk Subdivision. Note the yellow lines consist of Daisy Drive and the subdivision streets, highlighted in red is I-90. The blue arrow indicates the intersection of the highwall and East Daisy Drive.

A second, smaller sinkhole was discovered across the street to the East. This opening was caused by a roof failure in the old mine workings, due to the erosion of the gypsum.

Figure 7: October 2020 drone image of the sinkhole at 7013 East Daisy Drive, smaller sinkhole is indicated by arrow

Meade County Emergency Management officials evacuated fourteen houses along East Daisy Drive and the area has been uninhabited since early May. The South Dakota Department of Transportation commissioned an engineering study to ensure the safety of interstate ninety by determining if any voids lay under the highway. The study showed that there were no voids beneath I-90. The South Dakota Mines senior design team, Rapid Fill, visited the site on August 27th, 2020.

It is hypothesized that the structures at greatest risk are those that are built in the following areas: straddling the highwall, on fill material adjacent to the highwall, or over the underground workings.

Courses of Action

The following mitigation methods discussed are evaluated at a scoping study level. This implies an accuracy level or probability error of +/- 50% to costs displayed in this paper [15]. More accurately, this represents a preliminary economic assessment, used to make decisions to further study a project for viability. The conclusions herein should not be mistaken as a design basis report, as final costs and design specifications have not been analyzed. Preliminary bids and estimates from various firms are cited but are only estimates and cannot be used for costing in a final feasibility study. Upon completion of a final feasibility study and design basis report, the client will be able to make an informed investment decision.

Paste Fill

Overview

Paste fill and its use in mining originated in the mid to late 1970s, in Canada and South Africa, where paste was used for vertical ore veins, where miners could work above or below the paste (overhand or underhand cut-and-fill) fill without worry of rock burst [3]. Before this time, hydraulic fills did not contain cement content as a binder, it was only after the advent of commercialized Portland that mines could afford to employ this method [51]. Paste fill has been used in room and pillar mines like the Hideaway Mine in the past, utilized to mine out the pillars left in place to hold up the back of the mine, the paste fill sets and allows miners to extract the valuable pillars after initial mining has passed. Paste fill has also successfully allowed mines to dispose of tailings and mine waste that would normally take up space aboveground.

Today, several mines in North America employ this method for safe extraction, including the Lucky Friday, Galena, and Stillwater Mines [51]. Each of these mines use a slightly different mix for their paste fills but are relatively similar. Stillwater mine uses between 10 and 12% cement content and has a UCS or unconfined compressive strength of 85 psi after 7 days. This is lower than the other two mines, a result of a lack of larger aggregates in the paste. Galena uses 10% cement in their mix, as well as excess water, which is decanted through sand over the top of bulkheads. This mix yields a compressive strength of 375 psi after 7 days. Lucky Friday uses 8 to 10% cement, and no free water, which yields a compressive strength of 300 psi after 7 days. Modeled after these mines, the mix used in the paste fill for the Hideaway mine is 10% cement, and 60% solids, and yields an expected compressive strength of 300 psi.

The Hideaway hills mine paste fill analysis will use biproducts and other discounted products to offset costs. The materials used in the analysis are ASTM #57, Off-Spec Lime, and red clay, which is the overburden of the nearby Pete Lein limestone quarry. The mix ratio used will be 10% lime, 20% aggregates, 30% clay, and 40% water. The higher clay and fines content yields less friction with the pipe walls [50]. This will also decrease the chances of plugging in the delivery pipes. All aggregates and materials will be 1 inch passing, which will also assist in flowability for the mix.

The paste fill used in this analysis will be mixed above ground, then pumped below ground. Mixing and pumping will be conducted from a staging area across the highway, and the pipes will travel under the highway via culverts. The first step is to hydrate the lime, which takes place in the slaker. After the lime has been hydrated, it is mixed together with clay, more water, and aggregates in a Pug mill, which features opposite-rotating drive shafts and paddles. The resulting mix is homogeneous and ready to be pumped into the mine. The paste fill is loaded into the pumps via a hopper, and pumped into 5-inch steel pipes, into the mine.

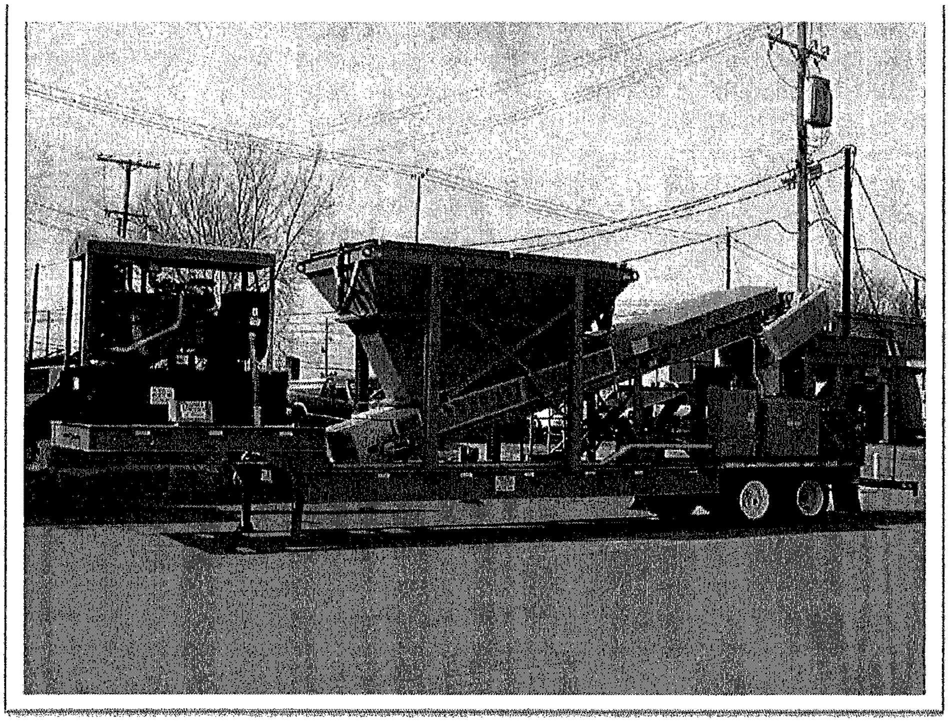

Figure 8: Portable PUG Mill [62]

The paste fill alone will not sufficiently remediate the damage caused by the mine collapse but will stop further collapse from occurring. In tandem with supports for the house foundations, as well as expanding foam beneath the houses, this method can be employed to remediate the site.

Bulkhead Design

The first stage of the paste fill method is the construction of bulkheads to contain the fill in the underground workings. Currently, there are two primary sinkholes that need to be closed off before the paste fill can be poured. The areas in which the bulkheads will be built will need to be prepped by consolidating any fill material into a stable base, as well as removing any large obstacles. The areas chosen for construction will be right at the beginning of the underground portions, which will allow construction but keeps workers out of the underground section.

The bulkheads must be designed in order to withstand the vertical pressure created by the overburden material, as well as the lateral pressure that will be applied by the paste fill. To calculate the pressure imposed on the bulkhead by the overburden, the average unit weight of the alluvium deposits and the Spearfish formation were used. Using a draw angle of 60 degrees and a unit weight of 23.5 kN/m^3 and projecting the area to the surface, force cones were created to determine overburden pressures and the bulkhead thickness.

The pressure created by the fill material is dependent on the cement percentage and the materials internal angle of friction. Using a Rankine's lateral earth pressure value of 0.51 for a fill material with a 10% cement content, the horizontal pressure that will be exerted by the paste fill is 42.82 kilopascals.

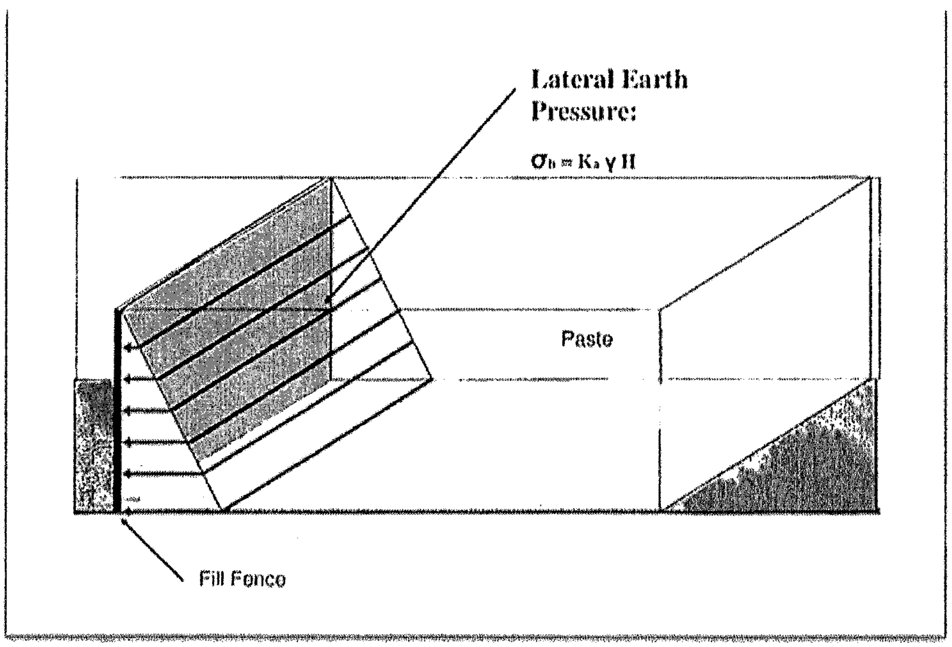

Figure 9: Lateral Pressure Acting on Bulkhead Structure [33]

Based on the area conditions and the calculated pressures, the most feasible design would be a timbered construction. Timber bulkheads are one of the easiest construction styles, and the materials are more common than those of other constructions. Timber bulkheads also utilize free drainage, to help eliminate pressure build up during fill pumping.

The construction of the bulkheads would use rough timber with dimensions of 5 inches thick and 13 inches wide, spaced at one-half inch, across the span of the openings. The side of the bulkheads that will be exposed to the paste fill will be lined with a PVC membrane, in order to retain particulate matter but promote the drainage of water. Based on previous studies, this construction would be able to withstand upwards of 95.8 kilopascals of pressure. After the bulkheads have been constructed and the void has been filled, the sinkholes can be filled in and compacted.

Building Stabilization

Overview

The subsidence caused by the mine has adversely affected many of the evacuated homes. The impacts from subsidence range from minor voids underneath sidewalks to massive cave-ins underneath the structures. A deeper analysis of each home could reveal more structural and foundational issues; however, this is beyond the scope of this report. The goal of stabilizing the structures is to prevent further settling and lift the structures back to their original height if needed. The stabilization of certain structures is reliant on the void being filled as mentioned in the previous section.

Steel Push Piers

A permanent solution to structural settling is hydraulic push pier technology. Steel piers have been used since the late 1800's and have seen improvements over the decades. [60] These are used in commercial and residential settings for stabilizing or mobilizing structures that have experienced significant subsidence. Evidence of subsidence includes cracked walls and stuck windows or doors.

Installation of Steel Push Piers

This sub-section will describe the installation of piers provided by Rapid Foundation Repair. [58]

1) **Site survey:** Pier placements are located around the structure and the location of underground utilities verified.
2) **Excavation:** Small excavations or the entire perimeter is dug for access at each placement location. The space required at the foundation is usually about 3 feet square.

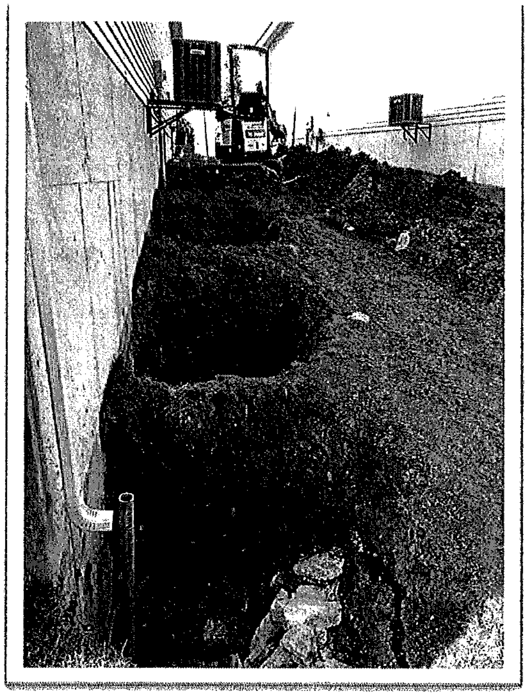

Figure 10: Excavation for the Footer Access. [54]

3) **Prep foundation:** This includes notching the concrete footing to place the push pier bracket under the stem wall, preparing the bearing area under the footing to a smooth and level condition, and adjusting the face of the stem wall to vertical at the point of bracket attachment.
4) **Bracket Attachment:** The steel resistance pier bracket is secured to the footing using anchor bolts. Then the drive stand and the hydraulic cylinder that is used to force the pier pipe into the soil is mounted on the drive stand.

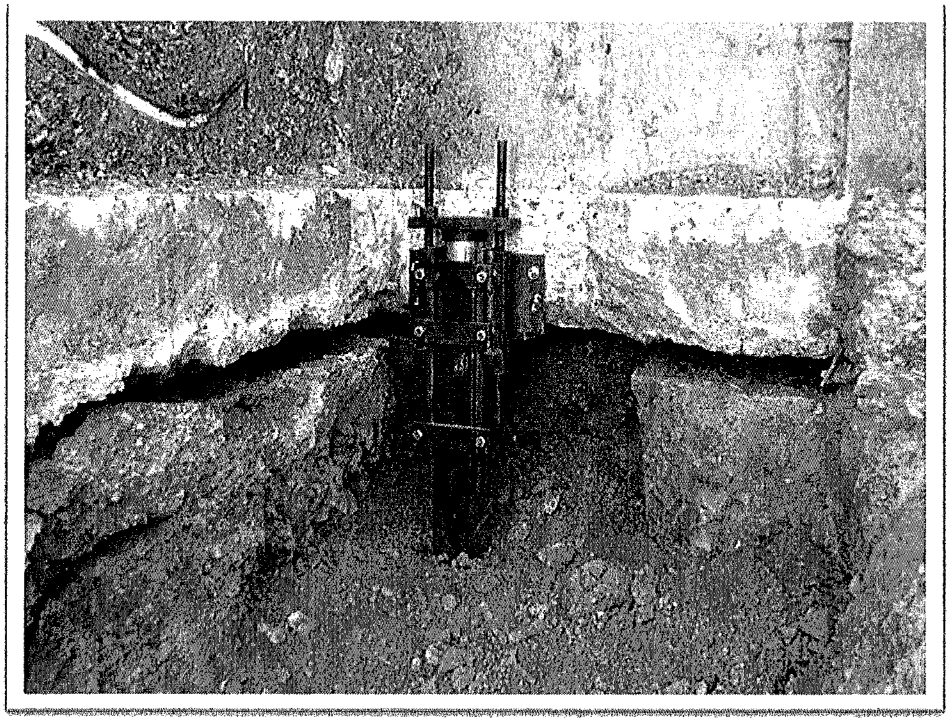

Figure 11: Installed Bracket [54]

5) **Push Pier Installation:** The steel pier is advanced into the soil using the structure as the reaction force with a 10,000-psi hydraulic pump and cylinder combination. The piers may be installed from outside or inside the structure. Pier installation continues until rock or suitable bearing stratum is encountered below the unstable soil near the surface.
6) **Load Test:** Every resistance pier is load tested by increasing the force on the pier to ensure the rock or bearing-strata will support a load greater than needed to guarantee a factor of safety. Typically, an engineer will determine the load of the structure and the desired factor of safety before the load tests are performed.

Figure 12: Steel Push Piers

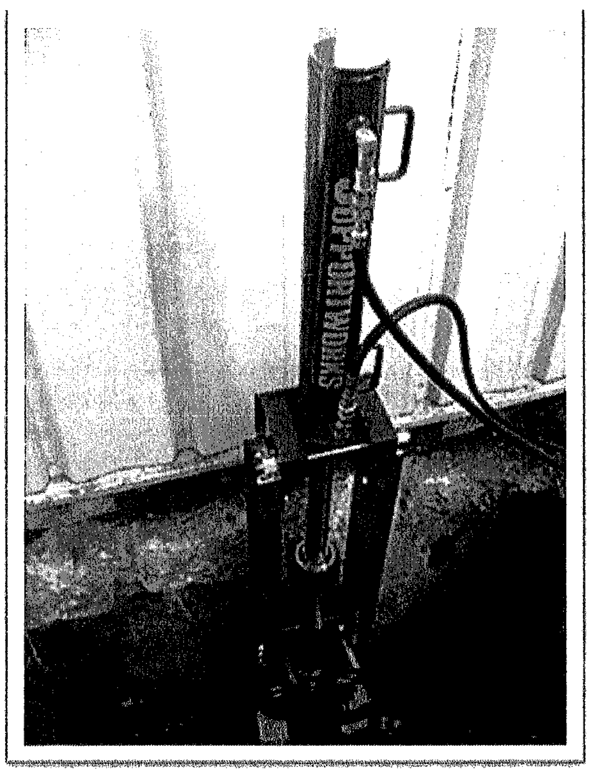

Figure 13: Hydraulic Pump used for Installation. [53]

7) **Prep for Restoration:** Once all push piers have been installed, load tested, and the installation data at each placement recorded; lifting head assemblies and hydraulic lifting rams are placed on the steel piers. The lifting cylinders are connected with one or more manifolds and operated using a hydraulic pump.
8) **Restoration:** Under careful supervision, the load is transferred from the existing failing strata under the foundation, to the load tested piers. The structure can be transferred gently and evenly lifted to as close to the original elevation or to the recommendation of the engineer. The nuts at the pier caps are secured at each placement and the lifting equipment is removed.
9) **Clean-Up:** The soil that was excavated at each steel push pier placement is now replaced and compacted.

If some structures require mobilization to their original heights, the smaller void created under the foundation can be filled with expanding polyurethane foam. Small holes are drilled through the foundation slab for installation of this product. There are two chemical components that simultaneously mix during the installation process. A set of the two components cost $2,000 for 55-gallon drums. The amount of component needed can be calculated after the event of lifting.

Mitigation Measures: Underground Support

Ground Control

Overview

This method will secure the ground and effected homes by supporting the underground workings. A ramp and portal will be excavated along the street into the underground workings. Shotcrete will be applied before steel sets are placed. These steel sets will progress throughout the interior of the workings. Bulkheads will be installed as the workings progress. A paste fill will be injected into the voids between the steel set structures to give additional support. After reclamation of the ramp and portal, a manhole cover will be installed in the street to permit reentry into the workings for maintenance. Several devices will be installed to monitor ground movement both on the surface and within the workings.

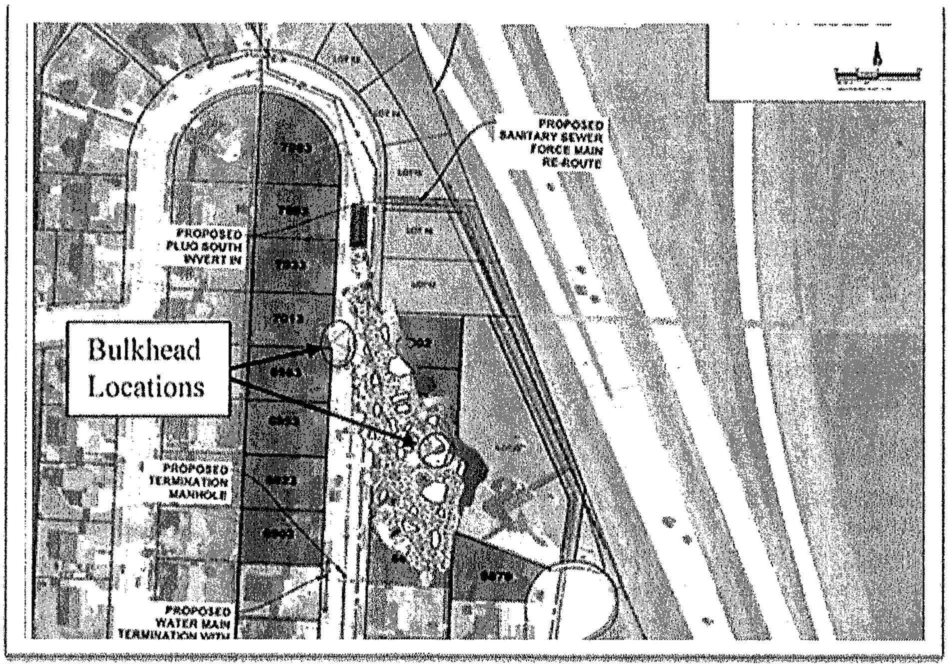

Figure 14: Proposed Sewer Main Re-Route and Bulkhead Locations

Phase 1 – Surface Preparation

Before progression into the workings can be performed, the sewer line running along the road must be re-routed. The plans for this project are show in Figure 14. A section of road will also need to be removed to make way for the ramp.

Phase 2 - Develop the Ramp/Portal

The ramp into the workings will be created at the northern end of the subdivision into the northern tip of the workings 25ft below the road. Lot #16 and #17 will be used for excavated

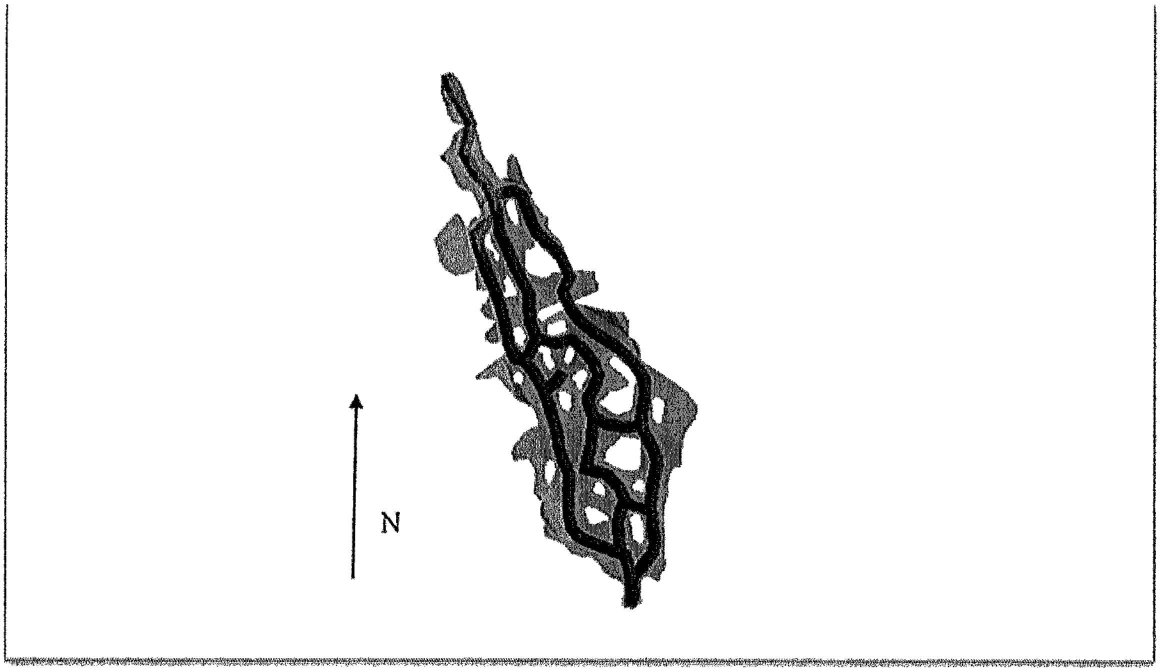

Figure 15: Steel Set Structuring

material as seen in Figure 14. [2] The sides of the ramp will be supported by steel mesh. The portal into the workings will be sprayed with shotcrete and will be the beginning of the steel set structure. [36] Once the portal is secured, a fan will be installed to provide the necessary ventilation required for progression through the workings.

Phase 3 – Support/Advance through Underground Workings

Shotcrete will be applied to the back before a steel set is set in place. [39] To correct the irregular shape of the workings, blockers will be inserted between the steel set and back to ensure proper load support. Paneling between the steel sets will ensure material stays outside of the structure. The shape of the steel set structure can be seen in Figure 16. [34]

To prevent more material from sluffing off into the mine workings, two bulkheads will be used in conjunction with the steel set structure. These bulkheads will be constructed as seen on Figure 14. The remaining areas of collapse will be filled by paste fill instead of bulkheads to support the ground. [33] The bulkheads will be constructed as progression of the underground steel set structure reaches them and makes a safe working environment for them to be installed.

To create an artificial pillar between the steel set structures, paste fill will be utilized. [29] Using drill holes from the surface, paste fill will fill the voids between the steel set structures.

Phase 4 – Remediate Ramp/Install access/Rebuild Road

After the underground structures are in place, the ventilation fan will be removed. To leave access to the workings for monitoring and repairs, a manhole shaft will be constructed at the entrance of the portal. [61] The steel mesh on the sides of the ramp will be removed, and the previously excavated material from lot #16 & #17 will be used to fill in the ramp. [20] Finally, the road around the manhole cover will be replaced.

Phase 5 – Monitor Subsidence/Perform Maintenance

To ensure that there is no subsidence and maintain the underground structures, monitoring equipment will be installed inside and on the surface of the workings. Using the manhole entrance, extensometers will be installed onto the steel sets. [21] Tilt meters will also be used on the surface. [21] Each of these instruments will give the necessary information to repair and monitor the condition of the underground structures. [37]

Mine Collapse and Reclamation

Overview

Unlike the other methods presented, this method is not designed to preserve the buildings above the mine. Rather, this method is planned to mitigate the danger of the void by removing it, and consequently removing the structures above. During this process, the surface buildings will be removed through demolition methods, the mine will be collapsed through the removal of pillars, and reclamation will be performed so that the land will be available for future development and use.

Phase 1 - Surface Structure Removal and Reconstruction

Before the mine collapse process can begin, the surface structures within the footprint of the mine and reclamation must be removed. For this analysis, it was assumed that an independent contractor would perform all work outlined in this phase. In total there are 12 buildings that lie in the footprint of the mine and will need to be removed. Additionally, there is a 140-foot-long section of road and sidewalks that must be removed. The utilities under that 140-foot section of road will also require removal.

After the reclamation phase of this project, the road and utilities will be replaced to re-establish this section of the neighborhood.

Phase 2 - Mine Collapse

Once the surface structures have been removed, the mine must be collapsed. The collapse of the mine will occur through drilling and blasting of structural pillars in various places of the mine. The blasting design includes 37 holes and a total of 1,550 feet drilled, with an average hole depth of 42 feet. Not every pillar will be blasted, only pillars that are large and/or still provide a substantial amount of structural support will be blasted. The image below displays the blasting design with the mine pillars.

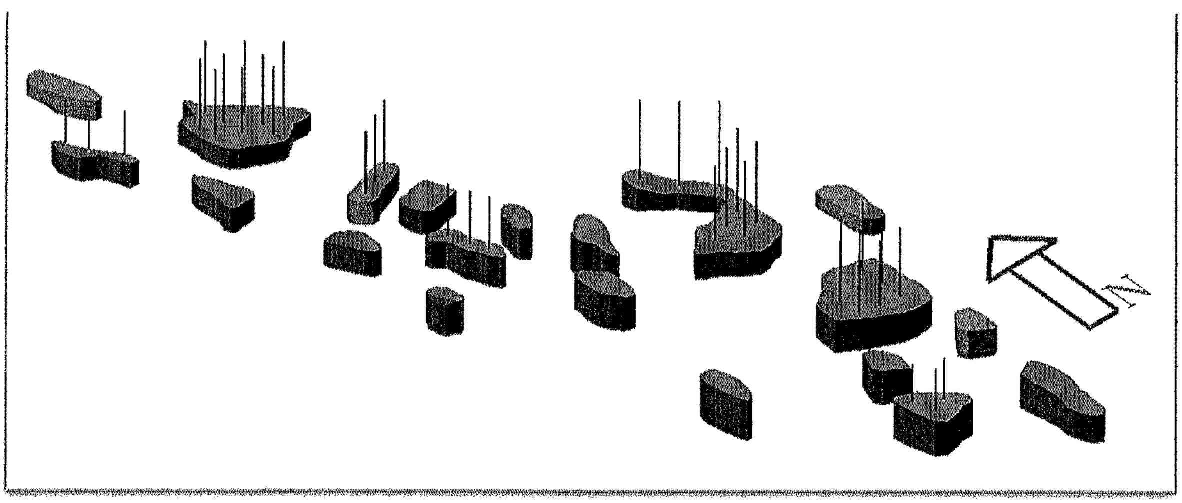

Figure 16: Mine Collapse Blast Design with Mine Pillars. Blast Holes in Blue, Pillars in Green

The blast holes are designed as 5-inch holes with a large amount of stemming material to help minimize flyrock. The powder column will only be the height of the pillar the hole is located in. Due to this blast taking place in a residential area, blasting mats will be used to provide an additional safety measure against flyrock.

Phase 3 – Reclamation

The final phase in this course of action is the reclamation phase, where the hole created from the mine collapse will be filled in and returned to the original pre-collapse topography. In total, the collapse will open a surface void of 33,000 cubic yards. Assuming the fill dirt will compact by a factor of 10% during the process of filling the hole, a fill dirt volume of 36,300 cubic yards will be required. The hole created by the collapse can be seen in the figure below.

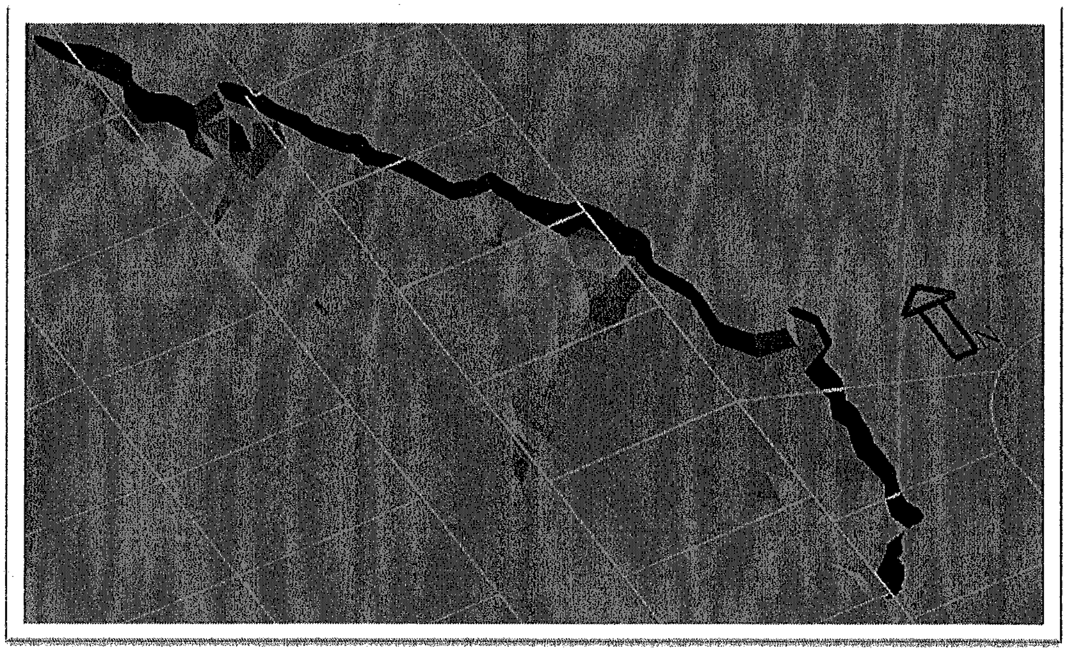

Figure 17: Hole Created by the Mine Collapse

The crew for this operation will consist of eight people in total. There will be five haul truck drivers, who will deliver the fill dirt in 15 cubic yard, highway, diesel dump trucks. To load those trucks there will be a loader operator, who, for the purpose of this study, is assumed to be operating a CAT IT28G Front End Wheel Loader. To receive the dirt at the hole will be a dozer operator, who is assumed to be operating a CAT D5 dozer. There will also be a project manager to keep things on track. The project manager is assumed to spend only half of the workday at working on the project.

It is assumed that the workday will be a 10-hour day, and a work week will be five days. Out of those 10-hour days, there is an allocated half hour for startup and shutdown, a half hour for lunch and a half hour for unscheduled delays. This leaves 8.5 hours of actual operation time. Assuming that the trucks are delivering dirt from Pete Lien, which is the closest source, and that the trucks would average 30 mph throughout their trip, 128 loads of dirt should be delivered each day. With 128 loads, an average daily production of 1,900 cubic yards should be achieved. At 1,900 cubic yards per day, the full project will take approximately 19 days, or about 4 work weeks.

When this process is finished the topography will be similar to the current topography, which will allow for reconstruction of the neighborhood, if desired. The land will be usable for any purpose deemed fit, and the threat of the void will be mitigated.

House Moving

To move the houses safely, the paste fill or underground support method must be in place. Moving a house requires purchasing land for the houses to be moved to as well as creating new foundations and all the associated utilities needed. Due to the logistical challenges associated with moving buildings, moves are typically only a mile or less as costs mount with increasing distance. [40] Using an average cost of 115,000 dollars for moving one house, the total to move all fourteen houses is 1,725,000 dollars, on top of the cost for making the ground safe. [44] Rapid Fill does not recommend this mitigation measure, as it is not feasible for the client to spend the money on making the ground safe in order to move the structures and then have to spend additional funds to move the houses, when making the ground safe is a feasible measure by itself.

Mitigation Measures: No Action

No Action

This section will explore the outcomes if no action is taken. This is primarily to establish a baseline to compare the other courses of action against. The loss of structures, utilities and land would be the main consequence of this course of action. In the event no action is taken the currently evacuated homes would remain evacuated for an indefinite amount of time. Due to limited rock sample availability and therefore limited rock testing data, it is uncertain how long the mine will be able to stand unsupported. The hole that the mine collapse would create would render the land in that area as useless as it is in the current situation, without any remediation efforts.

Cost Analysis

Paste Fill

This cost analysis details the paste fill option for stabilization within the parameters of the scope of work. Some assumptions that have been made to this point are a 5% of capital cost rate for renting equipment, as well as the availability of equipment and water and the startup lime. Shipping costs for pipe and equipment will depend on the firm that carries out the project and are not included in the estimate. The prices for the materials were received from Pete Lien, but their representative made it very clear that the costs are only to be used for academic purposes, not for future price expectations. Pete Lein is the best choice for materials, given their proximity to the site and their expertise is construction. Mine and construction equipment costs were taken from the Mine Costing Sheets, as were the costs of labor and benefits. [35] Overhead costs associated with engineers, managers, finance, and human resources will depend on the firm who carries out the project and will have to be included in the final feasibility. The analysis assumes that during each shift, there will be an hour and a half of breaks and cleaning, as well as additional time for maintenance and refueling. Drilling cost data was received from the Wyoming Department of Environmental Quality, Division of Abandoned Mine Land. Drilling costs were averaged from their projects drilling into abandoned coal mines and were assumed to be about equal to the costs of drilling for this project. The availability of trucks to haul material is assumed, and the price of hauling is assumed to be the national average per mile. The lime content used for the analysis is 10%, which is comparable to similar applications. Further analysis should include testing of the paste fill material to find compressive strength. Environmental studies and permitting will add to the cost of the project and will depend on the firm or government entity that carries out the project. Contingency costs are not applied to this cost analysis.

The parameters that were developed through analysis include the total volume of the void, found using the point cloud data generated from surveys conducted by the Paha Sapa Grotto. After the topography was developed above the mine from surveys, the approximate length of drilling needed was determined, found to be 2,261 feet, although this is an overestimate, as fewer holes could be drilled if the paste fill is as flowable as designed. The cost analysis assumed a less flowable paste, though this is likely not the case with the high water and fines content.

Materials costs were provided by Pete Lein and Sons, an aggregate and construction company in town with a quarry only 4.2 miles from the site. Costs were provided by the short ton and had to be converted to cubic yards for the sake of the cost analysis. These costs were provided for academic purposes and are not official price quotes. Approximate densities for the products were found from Auburn Aggregates. The three materials being used are ASTM #57, Red Clay, and Off Spec Lime, which is produced when a lime kiln starts up or shuts down. The analysis runs off the assumption that off spec lime will hydrate. ASTM #57 is quoted at $13.75 a ton, red clay at $2 per ton, and off spec lime at $20. Using approximate densities, ASTM #57 comes out to $17.46 per cubic yard, red clay at $1.22 per yard and off spec lime at $24.40 per yard.

Cost Analysis: Paste Fill

The paste fill method has been divided into four phases for simplicity, to provide a flowchart and order in which actions must be taken. Each phase must be complete before moving into the next phase, though the rerouting of the sewage lines can take place concurrently with phase one and two.

Phase 1

Phase one will involve drilling into the void from ground level, where paste will be pumped into to fill the void. Costs of drilling are based on drilling projects in residential areas in Wyoming in 2018. The drilling projects involved drilling into old coal mines, with the intention of supporting them. The per foot drilled average cost was approximately $34.94 per foot. [10] After analyzing the number of drill holes necessary to allow paste fill into every part of the mine, the total distance to drill is 2,261 feet. Total drilling requirements were based on drilling in locations to make sure that each area in the mine was filled, as well as several drill holes in the center to fill the center of the void. Several holes must be drilled where the back of the mine has collapsed, creating a cavity. This will take about 1.3 weeks to accomplish and in estimated will cost $79,013.

The cost per foot includes transportation, breaks, benefits, pay, safety, drill bits, gas, water trucks, and other assorted costs. Given the proximity of experienced drillers to the Blackhawk site, as well as drill rigs at the Pete Lein quarry, drill costs may go down compared to the example used. Non-percussive drills (such as a rotary drill) should be used to eliminate breakage in the back of the mine, avoiding caving.

Phase 2

Phase two includes setting up the pug mill, slakers, pumps, and pipe from the staging area to the mine site. The distance from the staging area to the mine is 480 meters. The work week for each laborer and for the foreman was calculated at 55 hours per week. This is an average work week based on the experience of the author. Including longer work shifts or night shifts will bring down the time of the project, as well as the rental payments for various equipment, but will increase labor costs. Further analysis based on actual quotes from contractors, as well as the availability of workers to fill those hours, will determine the best timeline to base the project on.

ASTM #57 will be used to support joints between the pipe sections, to make the pumps and pipe level and reduce pressure loss induced from changing elevations. Ridge Gilmour of Gilmour and Co., a Lime services contractor, provided the estimate for a monthly rental cost for two slakers at $7,500 per slaker, per month. This value is for purely academic purposes and cannot be used for quotes.

This estimate includes a repair cost per hour and maintenance that is applied to all equipment. This value was found in the Caterpillar Performance Handbook (ed. 44) and is used as the standard across all pieces of equipment. [35] This value includes lubrication, maintenance checks, parts replacement, and tire wear. The actual cost of maintenance will vary between the different equipment and should be considered in a final feasibility study for the project. Equipment availability is assumed at 85%, though this will vary based on the age and type of equipment. For instance, new drills have an availability of 90% in year one, and decrease in availability each year by 3%, leveling off at about 73%. Loaders are similar, having availability of 90-92% their first year and decreasing by 5% every year thereafter. [15] The final feasibility study based on actual equipment availability will provide more accurate expectations for availability and downtime.

The PUG mill capital cost is based on an actual sale of a used mill that meets the size and output requirements for this project. This capital cost may be replaced by a rental if available and is subject to change. Equipment, such as skid steers and pumps are assumed to operate at high use, though this will not always be the case, for the fuel consumption estimation. Fuel is projected to cost $1,378 for phase two. Benefits are assumed to cost 30% of wages, though this also may vary depending on the firm and if the workers are full or part time.

The total cost of phase two will be $222,911, including the assumptions laid out above. The total time to construct the pipe and set up the equipment for stage three will be approximately four weeks, assuming 55-hour work weeks and a three-person crew.

Phase 3

Phase three will involve the actual filling of the void with a paste fill. Slakers are used to hydrate the off-spec lime, which is then mixed with clay, aggregates, and water in the pug mill, and finally pumped using concrete pumps, through 5-inch pipes set up in phase two, and finally down the holes drilled into the Hideaway mine. Materials are brought from the Pete Lein quarry, and are assumed to be readily available, as well as trucks being available. The trucks used will be standard side dumps, with a capacity of 23 cubic yards. Water is assumed to be readily available at the rate of $3.42 per unit, the average of the area, where one unit is equal to 748 gallons. [41] Fuel is again estimated at the high operating use of $6.89 per hour, as well as the standard repair and maintenance cost per hour of $5.69. Costs will again vary by firm and availability of equipment, as well as the availability of trucks to bring materials from Pete Lein. The final cost of this phase comes out to $938,717, to be accomplished in 5.4 weeks. If availability of trucks or equipment increase this time, the cost will increase as equipment is rented for longer periods.

Phase 4

Phase four will involve the reclamation of the drill holes and disassembly of the pipes. Pipes and PUG mill are assumed to have no resale value. Cleaning of all the equipment and the deconstruction of the pipes will take approximately four weeks, and renting costs are applied for all equipment through the entire period. The sanitation district has provided an estimated cost of $350,000 for the rerouting of current utilities. With this cost added, the total cost of reclaiming and cleaning up the site comes to $469,870. This cost may increase if municipal or state inspectors call for more work on the site.

Cost Analysis: Paste Fill

The total cost of the project, including all four phases comes to $1,710,511. The total time this will take is about 15 weeks. Compared to the price of the homes and the value of the properties, this yields a price to cost ratio of 1.795. This option will be combined with bulkhead construction and home stabilization, to develop the final price to cost ratio.

This analysis is compared to the possibility of using a ready mix available from Pete Lein. The cost of the cheapest available ready mix is $74.75 per yard, which comes to a total cost of $2,236,819 for this option. This figure does not include the drilling costs, (available above) as well as the cost of shipping the material in concrete trucks to the site. This cost is about a half million greater than the cost of mixing the materials on site.

The final subtotals for each variable of the paste fill option are $62,256 for labor, excluding drilling, $199,530 for materials, $876,542 for equipment, and $469,870 for reclamation, with $102,313 in miscellaneous costs, including drilling. This yields a total projected cost of $1,710,511.

Building Stabilization

Four scenarios were created to estimate costs for stabilization. The same parameters were used for all cases. The only variable in these scenarios is the number of piers being used on the structures. Five homes are located over the void while nine are not. The void must be filled for these homes to be stabilized as the push piers are nested into each other as they are hydraulically pushed into the earth. They require constant resistance to stay seated. The other three scenarios were created to illustrate a spectrum of cost as each residence requires an inspection. Some homes may not need any stabilization while others might need the entire perimeter stabilized. Detailed tables of cost are in appendices 1, Tables 18-21. These tables consider each home and the number of piers it would require to stabilize them. The installation of a single pier is about $2,000 which includes labor. Other factors such as tax and concrete replacement are considered. The estimate for number of piers was calculated in person for each home for a more accurate assessment. The amount of time each home would take was calculated with a static crew size of eight workers and a supervisor. Below is a breakdown of each scenario with cost and number of days to complete each scenario.

Scenarios	Time of Completion	Estimated Cost
(1) Full stabilization all homes	109 days	$669,000
(2) Full stabilization of 5 homes above void, Partial of 9 homes	75 days	$457,000
(3) Full stabilization of 5 homes above void	45 days	$272,000
(4) Partial Stabilization of 9 homes NOT above void	30 days	$185,000

Table 1: This is a breakdown of the four scenarios of building stabilization. These can be found in appendices 1, 18-21 for more detail.

Cost Analysis: Underground Support

Ground Control

Phase 1 – Surface Preparation

The Ground Control course of action would start by rerouting the sewer main along the highway. This project is estimated to cost $350,000. This will be necessary to create a ramp into the workings. Before the ramp can be created, a section of road must be removed. Removing the road will cost $5,250. This means the overall cost of Phase 1 will be $355,250 as shown by Table 12.

Phase 2 - Develop the Ramp/Portal

Using a CASE 721G front end loader, the ramp will be constructed and covered in a steel mesh to prevent rock fall. [20] The total cost of the ramp construction is $4,340. [37] Once the portal into the workings is made, a fan will be needed to ventilate. The overall cost of Phase 2 will be $7,340 as shown by Table 13.

Phase 3 – Support/Advance through Underground Workings

As described above, shotcrete and steel sets are required to progress through the underground workings safely. One foreman and two laborers will be used to install these support systems. The overall cost of steel sets and shotcrete is $ 341,868. [39] As previously stated, 2 bulkheads will be needed, once underground, the bulkheads will be installed in order of arrival. The overall cost of bulkheads will be $20,598. [33] Between each steel set structure there will need to be paste fill. Using the information from the paste fill course of action, the overall fill cost will be $960,000. [29] This means the overall cost of Phase 3 will be $1,322,206 as seen in Table 14.

Phase 4 – Remediate Ramp/Install access/Rebuild Road

Once the underground workings are supported, the road will need to be restored and an access into the workings left behind. Using the same CASE 721G front end loader the ramp will be replaced using the same material removed before. [2] Several manhole precast rings will be left behind to provide access to the workings. The road will need to be repaired around the manhole cover. [61] This means the overall cost of Phase 4 will be $5,992 as shown by Table 15.

Phase 5 – Monitor Subsidence/Perform Maintenance

To get an accurate reading of the subsidence, 12 extensometers will be installed onto the steel sets to measure subsidence. 3 tilt meters will need to be used to accurately measure the workings. If any readings present issues, repairs may need to be done that will include future costs beyond this scope. The overall cost of phase 5 will be $45,150 as seen in Table 16. [21]

Total Cost Estimate

With every phase considered, the total cost of the ground control course of action is $1,735,938 as seen in Table 17.

Mine Collapse and Reclamation

Phase 1 - Surface Structure Removal and Reconstruction

Phase 1 of the Mine Collapse and Reclamation plan is surface structure removal. The reconstruction of roads, sidewalks and utilities has also been placed in this section for simplicity. For the purpose of this analysis, it is assumed that all work will be performed by independent contractors. It is also assumed that the homes to be removed must be purchased before removal begins. In addition to home demolition, home moving was also investigated. However, it was determined that home moving was not feasible due to the costs associated with moving a home, and due to the safety concerns of trying to maneuver heavy equipment on top of the mine without stabilization beforehand.

From a financial perspective, this phase can be broken down into two steps. The first step is to buy out and remove the houses that lie in the footprint of the mine. It is estimated that this step of the process will cost $2,678,400. The second step will be removing the road, sidewalks and utilities, and replacing them afterwards. This step is estimated to cost $300,000. In total this phase is estimated to cost $2,978,000. Most of the cost in this phase is the home buyout cost of $2,484,000. Excluding the home buyout cost, this phase is estimated to cost $494,000. A summary of these costs can be seen below in Table 2 and a complete breakdown of the costs in this phase can be found in Table 23 of Appendix 1.

Phase 1 Cost Estimate Summary	
Home Demolition	*$ 194,400*
Home Buyout	*$ 2,484,000*
Utility Removal and Relocation	*$ 300,000*
Total Cost	***$ 2,978,000***
Total Cost Excluding Home Buyout	***$ 494,000***

Table 2: Mine Collapse and Reclamation - Phase 1 Cost Estimate Summary

Phase 2 - Mine Collapse

Phase 2 of the Mine Collapse and Reclamation Plan is the actual collapse of the mine. This plan has been detailed in a previous section of this report. This section will cover the economics of the mine collapse plan.

From a financial perspective, this phase of the project can be broken into four main categories: blasting mats, drilling, labor and explosives and explosives accessories. The most expensive of these costs is the drilling cost at $54,200. The blasting mats come in at a price of $48,300, labor is estimated to cost $2,700 and the explosives and explosives accessories will cost $2,500. In total this phase is estimated to cost $107,700. A summary of these costs can be seen in Table 3 below and a breakdown of the costs in this phase can be viewed in Table 24 of Appendix 1.

Phase 2 Cost Estimate Summary	
Blasting Mats	*$ 48,300*
Drilling	*$ 54,200*
Labor	*$ 2,700*
Explosives and Explosives Accessories	*$ 2,500*
Total Cost	*$ 107,700*

Table 3: Mine Collapse and Reclamation - Phase 2 Cost Estimate Summary

Phase 3 - Reclamation

Phase 3 of the Mine Collapse and Reclamation plan is the reclamation process. The reclamation plan has been detailed in a previous section of this report, this section will cover the economics of the plan.

From a financial perspective this phase can be broken down into five main sections: cost of fill dirt, operator labor costs, trucking costs, loading costs and dozing costs. The cost of fill dirt is the highest cost at $436,000. Trucking costs are estimated at $68,200, labor will cost $49,900, dozing costs are estimated to be $12,600 and loading costs are $8,600. In total, this phase is estimated to cost $575,000. A summary of these costs can be seen below and a breakdown of these costs can be seen in Table 25 of Appendix 1.

Phase 3 Cost Estimate Summary	
Cost of Fill Dirt	*$ 436,000*
Operator Labor Costs	*$ 49,900*
Trucking Costs	*$ 68,200*
Loading Costs	*$ 8,600*
Dozing Costs	*$ 12,600*
Total Cost	*$ 575,000*

Table 4: Mine Collapse and Reclamation – Phase 3 Cost Estimate Summary

Total Cost Estimate

In total, this course of action is estimated to cost $3,661,000. The largest phase cost is phase 1 at $2,978,000, with a majority of that cost being the home buyout cost. Phase 2 is estimated to cost $107,700 and phase 3 is estimated at $575,000. The table below provides a summary of the costs of this course of action.

Total Cost Estimate Summary		
Phase 1 - Surface Structure Removal and Reconstruction	$	2,978,000
Phase 2 - Mine Collapse	$	107,700
Phase 3 - Reclamation	$	575,000
Total Cost	$	*3,661,000*

Table 5: Mine Collapse and Reclamation – Total Cost Estimate Summary

Cost Analysis: No Action

No Action

Because no action will be taken in this method, no direct costs will be incurred. However, the cost of the houses will be an indirect cost as they will be lost. If the same 15 houses that are currently evacuated are the ones that are lost and applying the cost factor used in the Mine Collapse and Reclamation section of $207,000 per home, the total value of the homes lost will be approximately $3,105,000. [17]

Recommendations

Overview:

Rapid Fill explored five courses of action for reclaiming or mitigating the collapse of the Hideaway Hill Mine. The first option includes using a paste fill, including bulkheads, and stabilizing the homes using push piers. The second option includes stabilizing parts of the mine, and filling others with paste. This option also includes the use of bulkheads, and the costs of stabilizing the homes. The third option is to remove the homes and road and accelerate the collapse of the mine using explosives. After collapse, the surface collapse would be redeveloped, and new homes could be built on it. The fourth option was the physical removal of the houses to a new area, after installing option one or two. The final option would be simply letting the collapse run its course and would include the cost of compensating homeowners for the value of their property and residences.

Recommendation:

After considering the cost, safety, environmental impact, and the longevity of each option, Rapid Fill recommends the demolition of the homes and accelerated collapse of the mine. This method is safer than the ground control course of action, and costs less than both ground control and paste fill. House moving was ruled out due to requiring the installation of either paste fill or ground control. The no action course was not recommended due to the safety hazard posed by the openings and the collapsing mine. The final cost for the recommended course of action is $3,412,000; most of which is dedicated to buying out the homes and the land.

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Appendices

Appendix 1: Tables

Materials	Per short ton	Per cubic yard
ASTM 57	$13.75	$17.46
Red Clay	$2.00	$1.22
Off Spec Lime	$20.00	$24.40

Table 1: Materials Costs provided by Pete Lein

Phase 1:	pump out water and drill
Costs in $/ft of drilling including setup/takedown, see "drilling" tab for further details	
estimated ft to drill	2261.378
Time (Weeks)	1.26437941
Cost per ft	$34.94
Total	$79,012.55

Table 2: Phase 1 Costs

Drill Project	Ft Drilled	Total
Fancher Lot	1453	$19,552
Community Park	2455	$118,056
East Rock Springs	2310	$125,680
Frontier Industrial Park	1859	$80,691
Quealy Rd	5860	$142,997
Total	13937	$486,976

	Cost per foot	$34.94

Table 3: Drilling costs, Wyoming 2018

DRILLING_PASTE_FILL		Feet drilled
DRILLING_PASTE_FILL	LINE_5	5.353
DRILLING_PASTE_FILL	LINE_7	14.983
DRILLING_PASTE_FILL	LINE_8	26.627
DRILLING_PASTE_FILL	LINE_9	38.9
DRILLING_PASTE_FILL	LINE_10	46.172
DRILLING_PASTE_FILL	LINE_11	49.281
DRILLING_PASTE_FILL	LINE_14	58.891
DRILLING_PASTE_FILL	LINE_15	66.334
DRILLING_PASTE_FILL	LINE_16	68.9
DRILLING_PASTE_FILL	LINE_17	74.035
DRILLING_PASTE_FILL	LINE_18	86.561
DRILLING_PASTE_FILL	LINE_19	90.666
DRILLING_PASTE_FILL	LINE_20	97.989
DRILLING_PASTE_FILL	LINE_22	98.71
DRILLING_PASTE_FILL	LINE_23	104.367
DRILLING_PASTE_FILL	LINE_24	115.183
DRILLING_PASTE_FILL	LINE_25	119.939
DRILLING_PASTE_FILL	LINE_27	127.884
DRILLING_PASTE_FILL	LINE_28	140.815
DRILLING_PASTE_FILL	LINE_29	148.65
DRILLING_PASTE_FILL	LINE_30	156.785
DRILLING_PASTE_FILL	LINE_32	164.329
DRILLING_PASTE_FILL	LINE_33	174.129
DRILLING_PASTE_FILL	LINE_34	185.895
total ft		2261.378

Table 4: Drilling data

Phase 2:						
Item	cost	week 1	week 2	week 3	week 4	Totals
Foreman Hrs.	$30.87	40	40	40	40	$4,939
Foreman Overtime Hrs.	$46.31	15	15	15	15	$2,778
Labor/Operator 1 Hrs.	$18.67	40	40	40	40	$2,987
L/O OT	$28.01	15	15	15	15	$1,680

Labor/Operator 2 Hrs.	$24.83	40	40	40	40	$3,973
L/O OT 2 Hrs.	$37.25	15	15	15	15	$2,235
Pipe + joints	$13,524.50	2	0	0	0	$27,049
Gravel (ASTM 57) Short Tons	$17.46	50	50	50	50	$3,493
Equipment (Skid Steer, operating high use) Fuel Units/Hour	$6.89	50	50	50	50	$1,378
Safety / Health	$213.63	3				$641
Benefits Based on per Hour basis	$23.92	165	165	165	165	$15,784
Slaker rental monthly (# Slakers Included in Cost)	$15,000.00	1				$15,000
Repair Cost per hour + Maintenance	$5.69	50	50	50	50	$1,138
Rental Cost Skid Steer / month (# Skid Steers Included in Cost)	$2,736.00	1				$2,736
Capital Cost: Used PUG Mill	$72,500.00	1				$72,500
Concrete Pumps Rental Cost	$16,150.00	4				$64,600
Total						$222,911

Table 5: Phase 2 Costs

Phase 3:	Fill void with paste	Weeks:	5.393824451
Item	cost	weekly quantity	Subtotal
	Work week per worker:	55	
Foreman Hrs.	$30.87	40	$6,660.29
Foreman Overtime Hrs.	$46.31	15	$3,746.42
Labor/Operator 1 Hrs.	$18.67	40	$4,028.11
L/O OT Hrs.	$28.01	15	$2,265.81

Labor/Operator 2 Hrs.	$24.83	40	$5,357.15
L/O OT 2 Hrs.	$37.25	15	$3,013.39
Truck trips #		389.76	
Trucking Cost per week	$1.82	$5,958.65	$58,494.65
Trucking Miles	8.4	3273.984	
Startup Lime S. Tons	$24.40	554.7826087	$73,014.56
Red Clay S. Tons	$1.22	1664.347826	$10,952.18
Gravel (ASTM 57) S. Tons	$17.46	1109.565217	$104,509.57
Water Units (1 unit = 748 gal)		3232.016446	
Water Cost	$3.42		$11,053.50
Equipment (Skid Steer, operating high use) Fuel	$6.89	165	$6,133.57
Benefits	$23.92	165	$21,284.34
Fuel (PUG Mill)	$6.89	165	$6,133.57
Repair Cost per hour + Maintenance	$5.69	432.4228056	$13,271.43
Rental Cost Skid Steer / month	$2,736.00	1.348456113	$19,899.85
Slaker Rental Monthly	$15,000.00	1.348456113	$109,100.03
Slakers, Pumps Fuel	$6.89	267.4228056	$9,940.95
Concrete Pumps Rental Cost	$16,150.00	5.393824451	$469,857.48
Total:			$938,716.85

Table 6: Phase 3 Costs

Phase 4:						
Item	cost	week 1	week 2	week 3	week 4	Totals
Foreman Hrs.	$30.87	40	40	40	40	$4,939
Foreman Overtime Hrs.	$46.31	15	15	15	15	$2,778
Labor/Operator 1 Hrs.	$18.67	40	40	40	40	$2,987
L/O OT Hrs.	$28.01	15	15	15	15	$1,680
Labor/Operator 2 Hrs.	$24.83	40	40	40	40	$3,973
L/O OT 2 Hrs.	$37.25	15	15	15	15	$2,235

Reclamation cost: reroute sewage (already Calculated)	$350,000.00	1				$350,000
Equipment (Skid Steer, operating high use) Fuel	$6.89	50	50	50	50	$1,378
Safety / Health	$213.63	3				$641
Benefits	$23.92	165	165	165	165	$15,784
Slaker rental monthly (# Slakers Included in Cost)	$15,000.00	1				$15,000
Repair Cost per hour + Maintenance	$5.69	50	50	50	50	$1,138
Rental Cost Skid Steer / month (# Skid Steers Included in Cost)	$2,736.00	1				$2,736
Concrete Pumps Rental Cost	$16,150.00	4				$64,600
Total						$469,870

Table 7: Phase 4 Costs

Trucking option	Per Yard	Total
Ready mix	$74.75	$2,236,819.00

Table 8: Ready Mix Cost

Labor sensitivity	Materials Sensitivity	Equipment Sensitivity	Reclamation Sensitivity	Total Cost	Cost to Price Ratio	Values	
$1,698,060	$1,670,605	$1,535,203	$1,616,537	$1,368,409	2.24	-20%	best case
$1,704,285	$1,690,558	$1,622,857	$1,663,524	$1,539,460	1.99	-10%	
$1,707,398	$1,700,534	$1,666,684	$1,687,017	$1,624,985	1.89	-5%	
$1,710,511	$1,710,511	$1,710,511	$1,710,511	$1,710,511	1.80	0%	
$1,713,624	$1,720,487	$1,754,338	$1,734,004	$1,796,036	1.71	5%	

$1,716,736	$1,730,464	$1,798,165	$1,757,498	$1,881,562	1.63	10%	
$1,722,962	$1,750,417	$1,885,819	$1,804,485	$2,052,613	1.50	20%	worst case

Table 9: Sensitivity of Costs for Paste Fill

Road Area	2100 ft^2
	Costs
Sewer Re-route	$ 350,000.00
Removal/ft^2	$ 2.50
Road Removal	$ 5,250.00
Phase 1	**$ 355,250.00**
Outputs:	
Sum Total:	**$1,710,511**
Subtotals:	
Labor	$62,256
Materials	$199,530
Equipment	$876,542
Reclamation	$469,870
Other	$102,313
Misc. Variables:	
Total Time (weeks):	14.658
Price to Benefit Ratio:	1.795
Avg Cost of Labor	$52.09

Table 10: Final Costs of Paste Fill

Inputs:	
Variables:	
Stope Volume (Cu Yards)	29924
Rental % Charged	5%
Unit Water Price (748 Gal)	$3.42
Value of Homes	$3,070,558
ASTM 57 ($/ton)	$13.75
Red Clay ($/ton)	$2.00
Off Spec Lime ($/ton)	$20.00
Trucking Cost per Mile	$1.82
Fuel ($/Gal)	$2.03
Work Week per worker hrs.	55
Shifts Per Day (6 day week)	1.0

Table 11: Final Variables for Paste Fill

Table 12: Ground Control Phase 1

Table 13: Ground Control Phase 2

Volume Fill	1540	yd^3
Bucket Size	3.5	yd^3
Buckets Required	440	
Cycle Time	1	min
Project Time	7.33	Hr
# of Shifts (rental)	1	
Costs		
Cost of a Shift	$ 465.00	
Labor Cost	$ 200.00	
Mesh Cost	$ 3,675.00	
Total Cost of Ramp	$ 4,340.00	
Fan Cost	$ 3,000.00	
Phase 2	**$ 7,340.00**	

Table 14: Ground Control Phase 3

# of Steel Sets	370	
Single Set Cost	$ 500.00	
Steel set Cost	$ 185,000.00	
Internal Surface Area of workings	8780	yd^2
Shotcrete thickness	25	mm
Shotcrete Required	240	yd^3
Shotcrete Unit Cost	195	$/yd^2
Shotcrete Cost	$ 46,800.00	
Shift Length	10	Hr
Single Set/Shotcrete Instillation Time	4	hr
Phase Length	1480	Hr
Phase Length	148	Shifts
Foreman Cost	30.87	$/hr

PASTE FILL CALCULATIONS

Inputs:	
Variables:	
Stope Volume (Cu Yrds)	21138
Rental % Charged	5%
Unit Water Price (748 Gal)	$ 3.42
Value of Homes	$ 3,070,558
ASTM 57 ($/ton)	$ 13.75
Red Clay ($/ton)	$ 2.00
Off Spec Lime ($/ton)	$ 20.00
Trucking Cost per Mile	$ 1.82
Fuel ($/Gal)	$ 2.03
Work Week per worker hrs	55
Shifts Per Day (6 day week)	1.0

Laborer Cost	21.75	$/hr
Labor Cost	$ 110,067.60	
Total Steel Set/Shotcrete Cost	$ 341,867.60	
Bulkhead 1 Area	488	ft^2
Bulkhead 2 Area	112	ft^2
Ash Board Cost	30.25	$/ft^2
PVC Membrane Cost	0.36	$/ft^2
Bulkhead 1 Cost	$ 14,937.68	
Bulkhead 2 Cost	$ 3,428.32	
Shifts Required	3	
Cost of a Shift	$ 744.00	
Labor Cost	$ 2,232.00	
Total Bulkhead Cost	$ 20,598.00	

Outputs:	
Sum Total:	$ 959,740
Subtotals:	
Labor	$ 54,895
Materials	$ 140,946
Equiptment	$ 565,140
Reclaimation	$ 469,870
Other	$ (271,111)
Misc Variables:	
Total Time (weeks):	13.075
Cost to Benefit Ratio:	2.344
Avg Cost of Labor	$ 52.09

Phase 3 Cost	**$ 1,322,205.60**

Table 15: Ground Control Phase 4

Volume Fill	1540	yd^3
Bucket Size	3.5	yd^3
Buckets Required	440	
Cycle Time	0.87	min
Project Time	6.38	Hr
# of Shifts (rental)	1	
Costs		
Cost of a Shift	$ 465.00	
Labor Cost	$ 200.00	
Total Cost of Ramp	$ 665.00	
Depth of Assess	$ 25.00	ft
Manhole Ring Depth	3.2	ft
Manhole Rings Required	8	
Manhole Ring Cost/Unit	$ 115.00	
Manhole Ring Cost	$ 920.00	
Shifts Required	2	
Shift Cost	$ 744.00	
Labor Cost	$ 1,488.00	
Total Manhole Ring Cost	$ 2,408.00	
Road Repair Cost/ft^2 (Including Labor)	$ 1.39	

Road Area	2100	ft^2
Total Road Repair Cost	$ 2,919.00	
Phase 4 Cost	**$ 5,992.00**	

Table 16: Ground Control Phase 5

# of Extensometers needed	12
Extensometer Unit Cost	$ 3,300.00
Extensometer Cost	$ 39,600.00
# of Tilt Meters Needed	3
Tilt Meter Unit Cost	$ 1,850.00
Tilt Meter Cost	$ 5,550.00
Phase 5 Cost	**$ 45,150.00**

Table 17: Ground Control Overall

	Cost	Description
Phase 1	$ 355,250.00	Surface Preparation
Phase 2	$ 7,340.00	Develop the Ramp/Portal
Phase 3	$ 1,322,205.60	Support/Advance through Underground Workings
Phase 4	$ 5,992.00	Remediate Ramp/Install access/Rebuild Road
Phase 5	$ 45,150.00	Monitor Subsidence/Perform Maintenance
Overall	**$ 1,735,938**	

Table 18: Building stabilization Scenario 1 (ALL HOMES FULLY STABILIZED)

Table 19: Building Stabilization scenario 2 (Homes above the void are FULLY stabilized AND other homes are PARTIALLY stabilized).

HOUSE NUMBER	**7093**	**7053**	**7033**	**7013**
NUMBER OF PIERS	6	8	12	13
PIERS/CREW MEMBER	0.75	1.00	1.50	1.63
ESTIMATED MAN HOURS	128.00	170.67	256.00	277.33
ESTIMATED DAYS	2.00	2.67	4.00	4.33

COST OF LABOR	($1,920.00)	($2,560.00)	($3,840.00)	($4,160.00)
FOREMAN COMMISION	($1,680.00)	($2,240.00)	($3,360.00)	($3,640.00)
CONCRETE REMOVAL (SQFT)		6.25		12
ESTIMATE FOR CONCRETE	$0	($31)	$0	($60)
TAX	($241.68)	($322.24)	($483.36)	($523.64)
COST OF INSTALLATION	($12,000.00)	($16,000.00)	($24,000.00)	($26,000.00)
TOTAL COST OF REPAIR	($12,241.68)	($16,353.49)	($24,483.36)	($26,583.64)
VALUE OF HOMES/PROPERTY	$193,688	$195,561	$288,614	$214,891
6983	**7002**	**6972**	**6953**	**6923**
11	26	17	10	10
1.38	3.25	2.13	1.25	1.25
234.67	554.67	362.67	213.33	213.33
3.67	8.67	5.67	3.33	3.33
($3,520.00)	($8,320.00)	($5,440.00)	($3,200.00)	($3,200.00)
($3,080.00)	($7,280.00)	($4,760.00)	($2,800.00)	($2,800.00)
		48	120	49
$0	$0	($240)	($600)	($245)
($443.08)	($1,047.28)	($684.76)	($402.80)	($402.80)
($22,000.00)	($52,000.00)	($34,000.00)	($20,000.00)	($20,000.00)
($22,443.08)	($53,047.28)	($34,924.76)	($21,002.80)	($20,647.80)
$188,583	$175,979	$199,963	$208,874	$201,628
6903	**6892**	**6912**	**6942**	**6879**
10	27	28	35	10
1.25	3.38	3.5	4.375	1.25
213.33	576.00	597.33	746.67	213.33
3.33	9.00	9.33	11.67	3.33
($3,200.00)	($8,640.00)	($8,960.00)	($11,200.00)	($3,200.00)
($2,800.00)	($7,560.00)	($7,840.00)	($9,800.00)	($2,800.00)
30	9	9	9	10
($150)	($45)	($45)	($45)	$0
($402.80)	($1,087.56)	($1,127.84)	($1,409.80)	($402.80)
($20,000.00)	($54,000.00)	($56,000.00)	($70,000.00)	($20,000.00)

($20,552.80)	($55,132.56)	($57,172.84)	($71,454.80)	($20,402.80)
$212,325	$187,509	$220,353	$205,268	$242,285
		TOTAL	($456,443.69)	

Table 20: Building stabilization scenario 3 (Only homes above the void are stabilized)

HOUSE NUMBER	**7093**	**7053**	**7033**	**7013**
NUMBER OF PIERS	0	0	0	0
PIERS/CREW MEMBER	0.00	0.00	0.00	0.00
ESTIMATED MAN HOURS	0.00	0.00	0.00	0.00
ESTIMATED DAYS	0.00	0.00	0.00	0.00
COST OF LABOR	$0.00	$0.00	$0.00	$0.00
FOREMAN COMMISION	$0.00	$0.00	$0.00	$0.00
CONCRETE REMOVAL (SQFT)		6.25		12
ESTIMATE FOR CONCRETE	$0	$0	$0	$0
TAX	$0.00	$0.00	$0.00	$0.00
COST OF INSTALLATION	$0.00	$0.00	$0.00	$0.00
TOTAL COST OF REPAIR	$0.00	$0.00	$0.00	$0.00
VALUE OF HOMES/PROPERTY	$193,688	$195,561	$288,614	$214,891

6983	**7002**	**6972**	**6953**	**6923**
0	26	17	0	0
0.00	3.25	2.13	0.00	0.00
0.00	554.67	362.67	0.00	0.00
0.00	8.67	5.67	0.00	0.00
$0.00	($8,320.00)	($5,440.00)	$0.00	$0.00
$0.00	($7,280.00)	($4,760.00)	$0.00	$0.00
		48	120	49
$0	$0	($240)	$0	$0

$0.00	($1,047.28)	($684.76)	$0.00	$0.00
$0.00	($52,000.00)	($34,000.00)	$0.00	$0.00
$0.00	($53,047.28)	($34,924.76)	$0.00	$0.00
$188,583	$175,979	$199,963	$208,874	$201,628
6903	**6892**	**6912**	**6942**	**6879**
0	27	28	35	0
0.00	3.38	3.5	4.375	0
0.00	576.00	597.33	746.67	0.00
0.00	9.00	9.33	11.67	0.00
$0.00	($8,640.00)	($8,960.00)	($11,200.00)	$0.00
$0.00	($7,560.00)	($7,840.00)	($9,800.00)	$0.00
30	9	9	9	10
$0	($45)	($45)	($45)	$0
$0.00	($1,087.56)	($1,127.84)	($1,409.80)	$0.00
$0.00	($54,000.00)	($56,000.00)	($70,000.00)	$0.00
$0.00	($55,132.56)	($57,172.84)	($71,454.80)	
$212,325	$187,509	$220,353	$205,268	$242,285
		TOTAL	($271,732.24)	

Table 21: Building stabilization scenario 4 (Only homes NOT directly over the void)

HOUSE NUMBER	**7093**	**7053**	**7033**	**7013**
NUMBER OF PIERS	6	8	12	13
PIERS/CREW MEMBER	0.75	1.00	1.50	1.63
ESTIMATED MAN HOURS	128.00	170.67	256.00	277.33
ESTIMATED DAYS	2.00	2.67	4.00	4.33
COST OF LABOR	($1,920.00)	($2,560.00)	($3,840.00)	($4,160.00)
FOREMAN COMMISION	($1,680.00)	($2,240.00)	($3,360.00)	($3,640.00)
CONCRETE REMOVAL (SQFT)		6.25		12
ESTIMATE FOR CONCRETE	$0	($31)	$0	($60)
TAX	($241.68)	($322.24)	($483.36)	($523.64)

COST OF INSTALLATION	($12,000.00)	($16,000.00)	($24,000.00)	($26,000.00)
TOTAL COST OF REPAIR	($12,241.68)	($16,353.49)	($24,483.36)	($26,583.64)
VALUE OF HOMES/PROPERTY	$193,688	$195,561	$288,614	$214,891
6983	**7002**	**6972**	**6953**	**6923**
11	0	0	10	10
1.38	0.00	0.00	1.25	1.25
234.67	0.00	0.00	213.33	213.33
3.67	0.00	0.00	3.33	3.33
($3,520.00)	$0.00	$0.00	($3,200.00)	($3,200.00)
($3,080.00)	$0.00	$0.00	($2,800.00)	($2,800.00)
		48	120	49
$0	$0	$0	($600)	($245)
($443.08)	$0.00	$0.00	($402.80)	($402.80)
($22,000.00)	$0.00	$0.00	($20,000.00)	($20,000.00)
($22,443.08)	$0.00	$0.00	($21,002.80)	($20,647.80)
$188,583	$175,979	$199,963	$208,874	$201,628
6903	**6892**	**6912**	**6942**	**6879**
10	0	0	0	10
1.25	0.00	0	0	1.25
213.33	0.00	0.00	0.00	213.33
3.33	0.00	0.00	0.00	3.33
($3,200.00)	$0.00	$0.00	$0.00	($3,200.00)
($2,800.00)	$0.00	$0.00	$0.00	($2,800.00)
30	9	9	9	10
($150)	$0	$0	$0	$0
($402.80)	$0.00	$0.00	$0.00	($402.80)
($20,000.00)	$0.00	$0.00	$0.00	($20,000.00)
($20,552.80)	$0.00	$0.00	$0.00	($20,402.80)
$212,325	$187,509	$220,353	$205,268	$242,285
		TOTAL	($184,711.45)	

Table 22: Rock Mass Rating Table

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS									
	Parameter		Range of values						
1	Strength of Intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	< 1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality *RQD*		90% - 100%	75% - 90%	50% - 75%	25% - 50%	< 25%		
	Rating		20	17	13	8	3		
3	Spacing of		> 2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	< 60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	< 10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	< 0.1	0.1, - 0.2	0.2 - 0.5	> 0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		
B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)									
Strike and dip orientations			Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable		
Ratings		Tunnels & mines	0	-2	-5	-10	-12		
		Foundations	0	-2	-7	-15	-25		
		Slopes	0	-5	-25	-50			
C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS									
Rating			100 ← 81	80 ← 61	60 ← 41	40 ← 21	< 21		
Class number			I	II	III	IV	V		
Description			Very good rock	Good rock	Fair rock	Poor rock	Very poor rock		

Table 23: Mine Collapse and Reclamation – Phase 1 Cost Breakdown

Phase 1 Cost Estimate		
Item Description		Units
Houses to be Demolished	*12*	*Houses*
House Demolition Cost	*$13*	*$/Sq. Foot*
Average House Area	*1056*	*Sq. Feet*
Demolition Permit Cost	*$75*	*$/House*
Debris Cleanup and Haulage Cost	*$2,400*	*$/House*
Average Demolition Cost	*$16,200*	*$/House*
Total Demolition Cost	*$194,400*	*$*
Average House Cost	*$207,000*	*$/House*
Total House Cost	*$2,484,000*	*$*
Total House + Demolition Cost	*$2,678,400*	*$*
Utility Removal and Relocation	*$300,000*	*$*
Total Cost	***$2,978,000***	***$***
Total Cost Excluding Home Buyout	***$494,000***	***$***

Table 24: Mine Collapse and Reclamation – Phase 2 Cost Breakdown

Phase 2 Cost Estimate					
Item Description		Units	Item Description		Units
Number of Blast Holes	*37*	*Holes*	*Primer Cost*	*$6.80*	*$/item*
Feet of Drilling	*1,550*	*Feet*	*Total Primer Cost*	*$250*	*$*
Drilling Cost	*34.94*	*$/Foot*	*Detonator Cost*	*$27.60*	*$/item*
Total Drilling Cost	*$54,200*	*$*	*Total Detonator Cost*	*$1,020*	*$*
Blast Pattern Area	*4,600*	*Sq. Feet*	*Surface Delay Cost*	*$560*	*$/100*
Blasting Mat Cost	*$10.50*	*$/Sq. Feet*	*Surface Delay Total Cost*	*$210*	*$*
Total Blasting Mat Cost	*$48,300*	*$*	*Total Blasting Cost*	*$2,500*	*$*
Lbs. Explosives Required	*2600*	*Lbs.*	*Hours of Drilling*	*60*	*Hours*
Explosives Cost	*$38*	*$/100 lbs.*	*Hours of Loading Holes/Blasting*	*20*	*Hours*
Total Explosives Cost	*$990*	*$*	*Total Labor Cost*	*$2,700*	*$*
Total Mine Demolition Cost	***$107,700***				

Table 25: Mine Collapse and Reclamation – Phase 3 Cost Breakdown

Phase 2 Cost Estimate					
Item Description		Units	Item Description		Units
Hole Volume	*33,000*	*Cubic Yd.*	*Total Truck Operating Cost*	*$68,200*	*$*
Compaction Factor	*10%*	*%*	*Total Dozer Operating Cost*	*$12,600*	*$*
Fill Dirt Required	*36,300*	*Cubic Yd.*	*Total Loader Operating Cost*	*$8,600*	*$*
Fill Dirt Cost	*$12*	*$/Cubic Yd.*	*Daily Truck Labor Cost*	*$1,730*	*$/Day*
Total Fill Dirt Cost	*$436,000*	*$*	*Daily Dozer Labor Cost*	*$335*	*$/Day*
Total Operating Hours	*160*	*Hours*	*Daily Loader Labor Cost*	*$335*	*$/Day*
Number of Trucks	*5*	*Trucks*	*Daily Project Manager Labor Cost*	*$250*	*$/Day*
Number of Dozers	*1*	*Dozer*	*Total Truck Operator Labor Cost*	*$32,600*	*$*
Number of Loaders	*1*	*Loader*	*Total Dozer Operator Labor Cost*	*$6,300*	*$*
Truck Operating Cost	*$85.30*	*$/Hr.*	*Total Loader Operator Labor Cost*	*$6,300*	*$*
Dozer Operating Cost	*$78.70*	*$/Hr.*	*Total Project Manager Labor Cost*	*$4,700*	*$*
Loader Operating Cost	*$54.00*	*$/Hr.*	*Total Labor Cost*	*$49,900*	*$*
Total Mine Demolition Cost	***$575,000***				

Appendix 2: Glossary of Mining Terms

This section has been adapted from The Northern Miner's 11th Edition of *Mining Explained* glossary of mining terms. [23]

Alluvium: relatively recent deposits of sedimentary material laid down in riverbeds, flood plains, lakes, or at the base of mountain slopes

ANFO: Acronym for ammonium nitrate and fuel oil, common blasting agent

Back: The ceiling or roof of an underground opening

Backfill: waste material used to fill the void created by mining an ore body

Back sample: rock chips (or samples) collected from the roof or back of an underground opening

Bankable: Acceptable to lenders as a basis for financing a project, most often used to describe definitive feasibility studies.

Bedding: Arrangement of sedimentary rocks in layers

Bit: cutting edge of a drill, frequently made of an extremely hard material such as industrial diamonds or tungsten carbide.

Blasting Mat: Mats comprised of heavy rope, steel or rubber which get put over the loaded holes before detonation to help contain the explosive force and reduce flyrock.

Collar: the top of a drill hole

Cut-and-Fill: a method of stoping in which ore is removed in slices, or lifts, and then the excavation is filled with rock or waste material (backfill), before the subsequent slice is extracted.

Decline: A sloping underground opening for machine access from level to level or from the surface, also called a ramp.

Deposit: a body of rock containing valuable minerals, usage generally restricted to zones of mineralization whose size has been wholly or partly determined through sampling.

Development: Underground work carried out for the purpose of opening up a mineral deposit. Include shaft sinking, crosscutting, drifting, and raising.

Dip: Angle at which a vein, structure, or rock bed is inclined from the horizontal as measured at right angles to the strike

Drift: A horizontal underground opening that follows along the length of a vein or rock formation as opposed to a crosscut which crosses the rock formation.

Face: The end of a drift, crosscut or stope in which work is taking place.

Feasibility Study: An economic study of a project which is considered bankable

Flyrock: Fragments of rocks thrown into the air during a blast.

Gypsum: A sedimentary rock consisting of hydrated calcium sulfate.

Hanging wall: Rock on the upper side of a vein or ore deposit.

Highwall: The excavated face of exposed overburden or side of a contour strip mine excavation.

Open-Pit: A mine that is entirely on the surface. Also referred to as open-cut or open-cast mine.

Passing Size: In mineral processing or metallurgical testing, the upper size limit of a specified fraction of the particles in a process.

Pillar: A block of solid ore or other rock left in place to structurally support the shaft, walls, or roof of a mine.

Portal: Surface entrance to a tunnel or adit.

Powder Column: The portion of the blast hole that is filled with explosives.

Reclaimation: the restoration of a site after mining or exploration activity is completed.

Rock burst: A violent release of energy resulting in the sudden failure of walls or pillars in a mine, caused by the weight or pressure of the surrounding rocks.

Rock mechanics: the study of the mechanical properties of rocks, which include stress conditions around mine openings and the ability of rocks and underground structures to withstand these stresses.

Room-and-Pillar Mining: A method of mining flat lying ore deposits in which the mined-out areas, or rooms, are separated by pillars of approximately the same size.

Rotary Drill: a machine that drills holes by rotating a rigid, tubular string of drill rods to which is attached a bit. Commonly used for large diameter blastholes in open pit mines.

Scaling: the act of removing loose slabs of rock from the back and walls of an underground opening, usually done with a hand-held scaling bar or with a boom-mounted scaling hammer.

Scoping Study: An early-stage study on the economics of a mining project used for development planning. Generally based on assumptions and estimated costs, is not considered bankable. May also be called a preliminary economic assessment.

Sedimentary (rocks): Secondary rocks formed from material derived from other rocks and laid down under water, examples are limestone, shale and sandstone.

Stemming: Stemming is a material that is put inside of a blast hole to help prevent gases from escaping upwards, confining the pressure and forcing it to through the surrounding rock rather than up through the collar.

Stope: A excavation in a mine from which ore is or has been removed.

Strike: the direction, or bearing from true north, of a vein or rock formation measured on a horizontal surface.

Tailings: material rejected from a mill after most of the recoverable valuable minerals have been extracted.

Undercut-and-fill Mining: A cut and fill mining method that works downward, with cemented fill placed above the working area, best suited for poor ground conditions.