0.1 Henderson Mine Overview

0.1.1 Introduction

The Henderson mine, located near Empire, Colorado, is situated in a stunningly beautiful area surrounded by snow-capped peaks and outdoor recreation facilities in Colorado's Rocky Mountains. Climax Molybdenum Company, a subsidiary of Phelps Dodge Corporation with corporate headquarters in Phoenix, Arizona, owns the Henderson Mine. Phelps Dodge is one of the largest mining companies in the world, and is primarily engaged in the production of copper and molybdenum from large open pit mines. The Henderson mine, which produces molybdenum ore by an underground mining method known as panel caving, is the company's only underground operation. Molybdenum is a grayish colored metal that is mainly used to produce high strength alloy steels. Other uses include chemicals and lubricants, and as filament supports in light bulbs.

The mine site is located 80.5 km (50 mi) west of Denver, Colorado and lies 3170 m (10,400 ft) above sea level on the eastern side of the Continental Divide. It can easily be reached from Denver International Airport (DIA) by taking Interstate 70 west to the Empire exit, Highway 40 approximately 16 km (10 mi) to the bottom of Berthoud Pass, and continuing approximately 3 km (2 mi) on the well maintained mine access road. The entire trip from DIA can be made in approximately 1.5 hours.

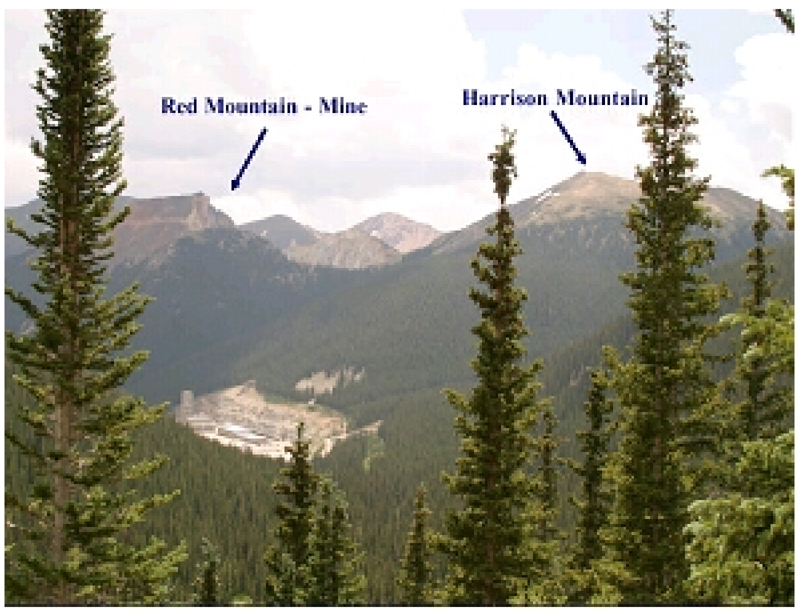

Figure H1. View of the Henderson Mine site showing mine buildings, Red Mountain mining area, and Harrison Mountain.

The mine site is within Clear Creek County and is surrounded by the Arapaho National Forest. The approximately 11.7 km^2 (2900 acre) of land containing the Henderson orebody, located underneath Red Mountain, as well as the proposed UNO site, located underneath Harrison Mountain

(Fig H1), is entirely privately owned by Climax Molybdenum Company. Additionally, the 52- km^2 (12,800 acre) mill site located near Kremmling Colorado is also entirely owned by the company.

The mine is currently producing about 21,000 tons of raw ore per day. It is estimated that the mine has adequate reserves for about twenty more years of production. Upon closure of the Henderson Mine, the company plans to re-open the Climax Molybdenum Mine located near Leadville Colorado

0.1.2 Geologic Setting

The Henderson deposit is composed of two partially overlapping ore bodies that lie 1,080 m (3550 ft) beneath the summit of Red Mountain. The ore bodies are entirely within a Tertiary rhyolite porphyry intrusive complex that has intruded the Precambrian Silver Plume granite. The deposit is elliptical in plan, with overall dimensions of 670 m by 910 m (2200 ft by 3000 ft), with an average thickness of 185 m (600 ft). The top of the deposit is at an elevation of 2610 m (8560 ft), while the lower limits range from 2,340 m (7680 ft) on the west to 2,100 m (6900 ft) on the east. The mineralization is relatively continuous in the ore bodies and consists of molybdenite and quartz in random intersecting closely spaced veinlets. The general nature of the orebody and the surrounding host rock is that of very competent (high strength) granite with compressive strengths ranging from 100 to 275 Mpa (14,500 to 40,000 psi). Host rock areas that have very little molybdenite have been found to behave appropriately for medium-strength granite.

The proposed UNO facilities will be located under Harrison Mountain, which is situated just to the west of Red mountain (Fig H1). Regional geologic studies have indicated the Harrison Mountain area to be barren of mineral deposits, and for this reason extensive exploration drilling has not been performed. The Henderson Geology Staff carried out detailed surface mapping of Harrison Mountain in the early 1980's. This mapping revealed highly competent Precambrian Silver Plume Granite along the crest of the mountain, and on the northeast and southeast-facing slopes. Broad zones, up to 300 m (1000 ft) wide of northeast-trending broken and fractured granite were mapped along the upper northwest slopes below the ridgeline. This broken zone lies within the overall trend of the Vasquez Pass Shear Zone. The downward extent of this broken zone is not known. It does, however, project to the northwest of the proposed UNO excavation, one mile below the peak.

The only exploratory drill hole located on Harrison Mountain was CX-126, drilled in 1968 from an elevation of 3502 m (11,489 ft) on the southeastern slope. The hole was drilled from an access road below the saddle that separates Harrison from Red Mountain, and is above the trace of the proposed access tunnels on 7500 Level. The vast majority of the core was in Precambrian Silver Plume Granite, with minor intervals of Idaho Springs Schist that occur as inclusions. What is noteworthy in this hole is that the Silver Plume Granite becomes more competent with depth, beginning at around 2957 m (9,700 ft) in elevation. Rock competencies range between 6 to 8 (with 9 being maximum). The contact between Silver Plume and Urad Porphyry is at an elevation of 2654 m (8706 ft), with rock competencies remaining high to the end of the hole at an elevation of 2294 m (7526 ft). The bottom of this hole is very close to the 9HW-99LD intersection on 7500 Level. This intersection is the preferred location of a 600 m (2,000 ft) exploration drill hole to the west under Harrison Mountain. Diamond drill holes to the north of CX -126 corroborate the high rock competencies seen in that drill hole. Drill holes CX-135 and CX-103 both show high competencies in the Silver Plume Granite and in the Urad Porphyry. Silver Plume Granite has historically been a competent unit during underground development at the Henderson Mine. On the 7500 Level, the Granite remained competent in 9A and 9HW drifts. Based on the detailed geologic logs from surface exploration diamond drill holes and the information gathered by mining through the Precambrian units on the 7500 Level, the proposed large UNO excavation under Harrison Mountain should be in competent Precambrian Silver Plume Granite. Exploratory drill holes from the 7500 Level will be necessary to verify this conclusion.

0.1.3 Mine Description

The mine began operation in 1976 after a 10-year predevelopment program and a $500 million investment. The Henderson 2000 modernization program, which consisted of the new underground crusher room excavation, conveyor transfer station excavation and conveyor decline, was begun in 1996 and was completed in 1999. From the beginning, the mine was designed as a high capacity operation, and the mine infrastructure is engineered to support production in excess of 30,000 tons per day, which equates to about 10 million tons per year, easily making the Henderson Mine one of the 10 largest underground mines in the world today.

The mine is accessed from the surface by an 8.53 m (28 foot) diameter men and material shaft that extends down to the 7500 level. The shaft cages can transport up to 200 people at a time, and the trip from the surface to the 7500 level takes about 5 minutes. The cage can accommodate loads with maximum dimensions 2.6 m wide, 7.1 m long, and 3.9 m high (8'-7"w x 23'-5"l x 12'-11"h) weighing up to 30 tons. Taller items up to 5 m in height (16' 4") can fit on the cage if they are small enough to fit in one corner. Loads of up to 50 tons can be carried if a crosshead is substituted for the cage and counterweights used. An inter-level ramp with a grade of about 7% extends from the 7500 level down to the 7065 truck level.

From the 7700 production level, ore is transported with large capacity Load Haul Dump units (LHDs) with capacities of about 10 tons per scoop, to bored 2.5 m diameter ore passes that extend vertically down to the 7065 truck level. On the 7065 truck level, ore is loaded from large ore chutes at the bottom of the ore passes into 80 ton side dump underground haul trucks, (the largest underground trucks manufactured), which haul the ore to the underground crusher. The crusher reduces the size of the ore to pieces 8 inches or less, and has a capacity of 2300 tons per hour.

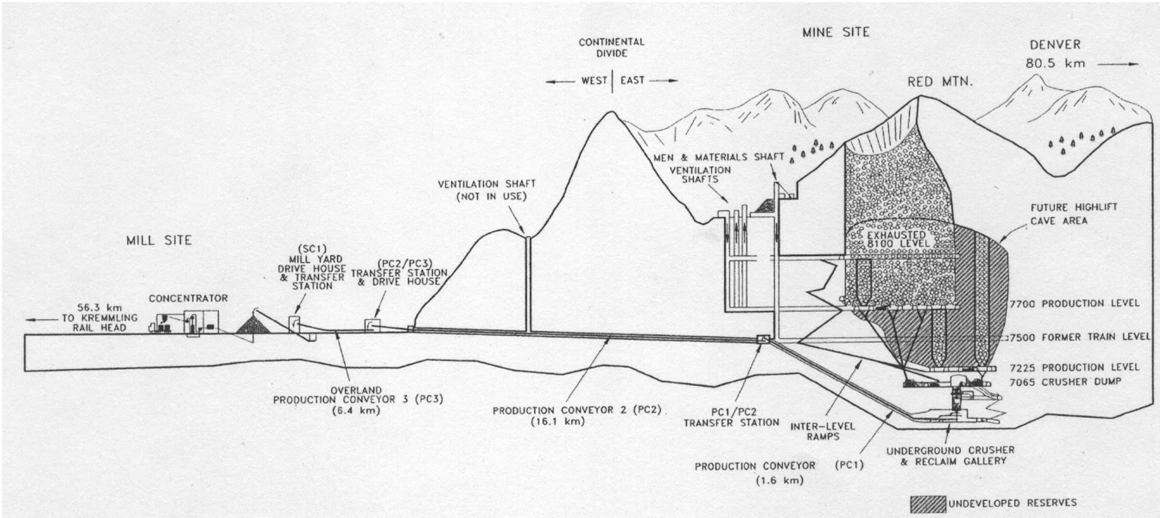

Figure H2. Idealized cross section of the Henderson Mine infrastructure.

From the bottom of the crusher below the 7065 level, the ore is loaded on to the first of three conveyor belts, PC1, which transports the ore 1.6 km (1 mi) to the PC1/ PC2 transfer station located at the 7500 level. At the transfer station, the ore is then loaded onto the PC2 underground conveyor, and is transported 16.1 km (10 mi) under the continental divide to the PC2/PC3 transfer station. PC2 is the longest single flight conveyor in the world. At the PC2/PC3 transfer station the ore is loaded onto the 6.4 km (4 mi) long PC3 overland conveyor that transports the ore to stockpiles for subsequent processing at the mills. The entire journey from the bottom of the crusher to the mill stockpile takes about 2 hours. Mill tailings are placed in large containment areas that will be reclaimed and re-vegetated when the mine is closed. The operating permit allows for the deposition of in excess of 340 million tons of mill tailings.

From 1976 through 1991, approximately 98 million tons of ore were produced from the 8100 level. In 1992, the 7700 level was brought into production and over 70 million tones have been produced from this level so far. The next production level will be at the 7210 level, located 149 m below the 7700 level.

Ventilation to the production level is supplied by a multi horizon level 15 to 20 m (50 to 65 ft) below. Both intake and exhaust air are transported on two horizons to provide a general north-to-south fresh air-to-exhaust airflow. Each production ore pass is connected to exhaust air and has an associated intake raise from the intake drifts. This entire level is connected to an 8.5-m (28-ft) intake shaft and to 7- and 10-m (23- and 33-ft) exhaust shafts by way of several 5- by 5-m (16- by 16 ft) ventilation drifts. Approximately 3.2 million cubic meters per hour (1.9 million cfm) of air is moved through the mine.

a b

Figure H3. Large mining equipment used at the Henderson mine. a) 10 ton capacity Load Haul Dump unit (LHD). b) 80 ton capacity side dump underground haul truck.

Mine water is treated at the Urad Water Treatment Plant, which was built in 1996 with a $9.8 million capital investment. The plant is capable of treating 15 m^3/m (4000 gpm) using a two-stage lime precipitation process for removal of manganese, zinc, aluminum, and other metals. The treated mine water is discharged into Clear Creek and used by various communities down stream.

The Henderson Mine is the second largest consumer of electricity in Colorado. A permanent substation that is integrated into the statewide electricity distribution network is located on the property.

Two MSHA approved emergency escape routes for the safe evacuation of mine personnel in the event of a mine emergency exist. The primary escape way is Number 2 Shaft, and the secondary escape way is through the PC2 tunnel. These routes would be available for use in the UNO emergency evacuation plan.

The largest excavations in the mine were constructed as part of the Henderson 2000 project. These were the PC1/PC2 transfer station, 12.8 m wide x 27.5 m long x 17.7 m high (42 ft x 90 ft x 58 ft) constructed in Silver Plume Granite, and the underground crusher station 18.6 m wide x 28.3 m long x 14.6 m high (61 ft x 93 ft x 48 ft), constructed in the Vasquez Porphyry rock type.

0.1.4 UNO Specifics

The proposed location of the UNO room (Fig H4) is directly below the summit of Harrison Mountain, elevation 3750 m (12,300 ft). Because of the availability of the large capacity shaft and mine tunnels developed as part of the infrastructure for the Henderson mining operation, the amount of development in the form of access tunnels for the proposed UNO laboratory will be minimal.

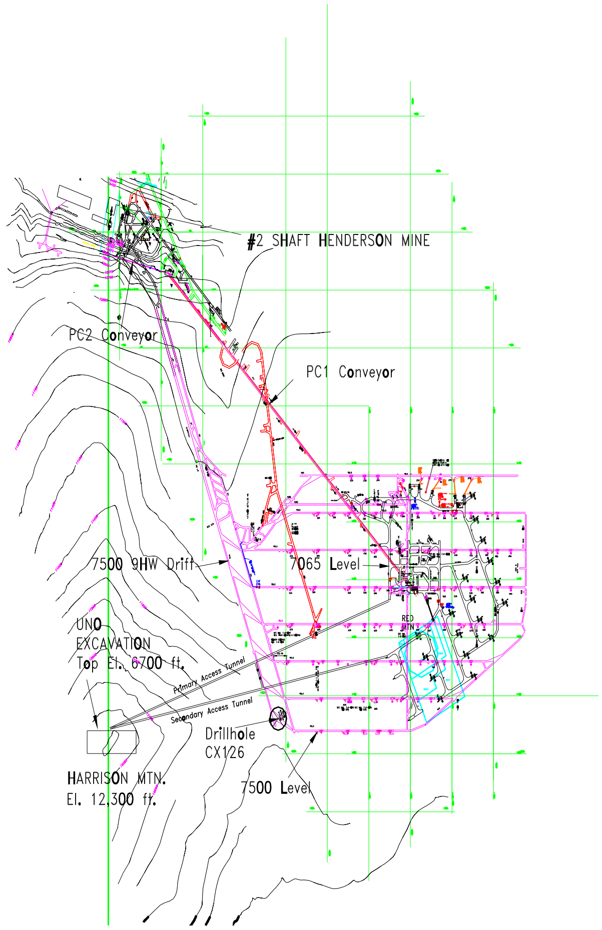

Figure H4. Plan view of Henderson Mine workings and proposed UNO location. (Scale: 500 feet between map gridlines)

A number of different layouts could be used to access the area under Harrison Mountain from the existing mine tunnels. One possible approach is discussed below. While the details of the exact final layout will most likely differ slightly from that outlined, the final costs estimates are expected to be about the same as those summarized. Two tunnels would provide access (Fig H4). The primary access tunnel would be driven from the 7065 truck level (elevation 2153 m) and would provide the access for people and materials to the UNO laboratory area. This tunnel would be 6 m wide and 5.5 m high (20 by 18 ft) in cross section and would be driven at a 10% grade downward for a distance of approximately 1103 m (3620 ft). The elevation at the end of the tunnel at the UNO room location would be about 2044 m (6705 ft), resulting in a total depth of 1705 m (5595 ft) below the summit of Harrison Mountain. Estimates for the UNO project are that a depth of 1525 m (5000 ft) is required, which gives a margin of safety with the proposed layout of about 181 m (595 ft). A vertical section through Harrison Mountain showing the approximate location of the

UNO room relative to the surface is given in Figure H5. Note that the additional 110 m (360 feet) of elevation that can be gained by driving the access tunnel at a 10% decline rather than horizontal can be realized at a relatively minor additional cost, i.e. approximately 6 m (20 feet) of additional horizontal tunnel would be required to gain 110 m (360 feet) of depth. It is expected that large trucks carrying supplies would access the laboratory area through this tunnel. Although grades of up to 15% on haulage roads are occasionally used in the mining industry, it is felt that for safety reasons, grades greater than 10% should be avoided for the primary access tunnel.

A second tunnel will also be driven from the 7065 truck level. The purpose of this tunnel is to provide for ventilation requirements, and to serve as a secondary escape route. The dimensions on the secondary tunnel will be 3.7 m by 3.7 m (12 ft by 12 ft). This tunnel will be driven at a grade of 10.6% for a distance of 1036 m (3400 ft). A grade greater than 10% is acceptable since the secondary access tunnel will not be used for the transportation of personnel and materials. Although this tunnel will provide secondary access, if the UNO project is approved, this tunnel should be driven first since the overall cost per foot are lower than the larger primary access tunnel cost. It is expected that a second detailed program of diamond drilling in order to better quantify the geotechnical parameters of the rock mass to be used in the final design of the UNO laboratory will be done from this tunnel.

A short crosscut drift approximately 85 m (280 ft) in length will be driven connecting the primary and secondary drifts at approximately the location of the 9HW drift. To provide for ventilation requirements, two vertical 3 m (10 ft) diameter, 183 m (600 ft) long bored raises will connect the crosscut to the ventilation drift below the 9HW drift on the 7500 level. In addition to these openings, it is estimated that 150 m (500 ft) of tunnels 6 m x 5.5 m in area will also be required for various shops, access to the UNO chamber, etc. The total time required to construct the access tunnels would be around nine months to one year.

The proposed UNO room will have dimensions of 60 m wide, 60 m high, and 180 m long (200 x 200 x 600 ft). Including the arched opening over the room, it is estimated that about 1 million m^3 (35,315,000 ft3) of rock will have to be removed for the excavation. Using a tonnage factor of 12.75 ft3 /ton, this volume represents about 2,780,000 tons. Including the volume required for the tunnels and other openings, the total tonnage required for the entire UNO excavation is estimated to be roughly 3 million tons. The waste rock produced will be removed by the Henderson ore transportation system at an estimated cost of $7.50/ton. A truck loading station will be constructed and used to load the broken rock into the underground haulage trucks. Broken rock will be trucked to the crusher station and removed from the mine using the existing conveyor system. Note that the total excavation volume of 3 million tons will easily fall within the current operating permit for the mine, which allows for the deposition of over 340 million tons at the mill site. 172 million tons have already been deposited and an additional 166 million tons will be deposited during the remaining mine life. No additional permitting should be required for the disposal of the waste rock produced by the UNO project.

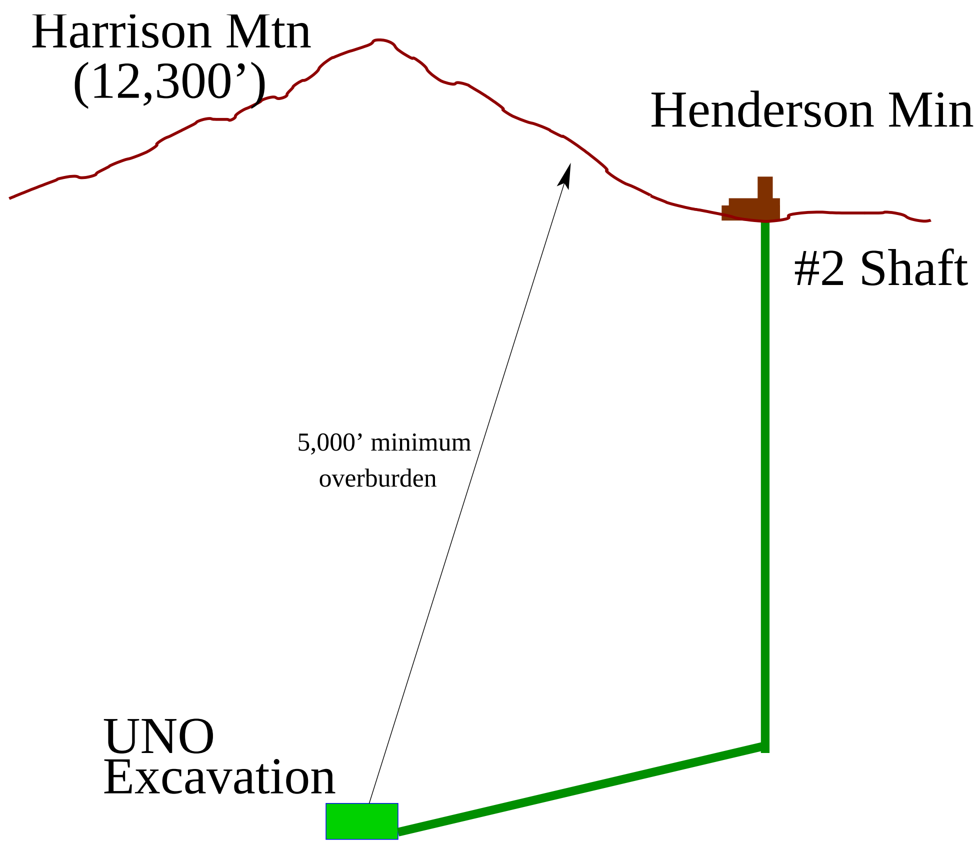

Figure H5. Vertical section through Harrison Mountain showing approximate location of the UNO room.

Based on the above information, a preliminary estimate of the excavation costs for the proposed UNO laboratory has been performed (Table H1). Cost estimates are based on actual costs from the Henderson 2000 project. Costs for the large UNO chamber are estimated lower than the costs for mining the underground crusher chamber because of efficiencies that will be gained from the large volume of this chamber.

In order to facilitate the comparison with other potential sites, excavation costs have been broken down into access costs, and excavation costs for the large UNO room. Excavation costs for the UNO room will most likely be approximately the same regardless of where the laboratory is located. The total access cost of about $8 million is a fraction of the $50 to $150 million that would be required for access at other potential underground laboratory sites, (Homestake, Soudan, San Jacinto, Icicle Creek). Additionally, the $7.50 per ton cost for rock removal and permanent deposition is significantly lower than what would be expected at any of the above named sites.

Cost Description	Units/Type	Units	$/unit	Cost
A. Initial exploration and ventilation tunnel (12'w x 12'h drifts)	A. Feet	3680	$ 500	$1,840,000
B. Ventilation	B. Mobilization	1	$29,200	$29,200
10 ft diameter	Setup	2	$18,000	$36,000
2× 600 ft	Feet	1200	$300	$360,000
C. Primary access tunnel (20'w x 18'h drifts)	C. Feet	3900	$1,100	$4,290,000
D. Truck loading station	D. Construction	1	$500,000	$500,000
E. Cost for rock removal	E. Tons	115,025	$7.50	$862,687
	Total-Access			$7,917,887
F. UNO room excavation	F. Cubic Feet	35,315,000	$1.70	$60,035,500
G. Cost for rock removal	G. Tons	2,769,804	$7.50	$20,773,529
	Total-UNO room			$80,809,029
H. Contingency		30%		$26,618,075
	Grand Total			$115,344,991

Table 1: Estimated UNO excavation costs.

At the anticipated depth of the UNO experiment of 4200 mwe under Harrison Mountain several other Gran Sasso style experimental halls could be provided to co-site additional experiments. The details of size and infrastructure needs would have to be discussed to include them in the planning process. If greater depths are required for an experiment a ramp (again with 10% slope) could branch off the ramp leading to the UNO site and wind down under Harrison Mountain. Secondary access would be provided by a smaller escape ramp. Using this style of access a depth of 5320 mwe could be provided for experiments with about $23 M additional cost.

It is estimated that the Henderson Mine will be in production for about twenty years. During the UNO construction period estimated to be about five years, a certain amount of coordination between the mine and the construction personnel will be required regarding the use of the shared access routes such as the vertical shaft and the ramp down to the 7065 truck level. This coordination is not expected to be much of a problem since the people involved in the construction phase will be trained mining personnel. The details of a suitable schedule for use of the shared access routes will have to be worked out for the 10 to 15 years that UNO facilities will be in use while the mine is in production. After production ceases, the mine infrastructure required to provide access and services to the UNO area will have to be operated and maintained.

The costs of operating the facility once the excavations are complete will be estimated at a later date when more information regarding the needs of the UNO project is available. It is expected that operating costs at Henderson would be in line or lower than operating costs that would be found at other potential underground laboratory sites. The exact details of the required operating contract as well as the long-term lease or ownership of the mine will also have to be worked out at a later date.

A summary of other mine infrastructure that exists as well as what would be available to the UNO project is given below:

- Mine ventilation: The mine ventilation system has a capacity of 1,900,000 cubic feet per minute (cfm) provided through three large surface fans. Of this total amount, about 200,000 cfm in excess capacity would be available to UNO, which is significantly more than the estimated 50,000 cfm that would be required to ventilate the large UNO room and access tunnels.

- Electricity: Two 24 Megawatt transformers for a total of 48 Megawatt are available at the mine site. The mine is currently using 10 Megawatt, but also requires an additional 10 Megawatt for backup. With the existing transformer stations, UNO would have 14 Megawatt available with 14 Megawatt for backup. The electrical network has 100% redundant feed from the power company Xcel, from the Cabin Creek substation near Georgetown and Blue River substation located between Kremmling and Silverthorne.

- Mine dewatering: The mine pumping and dewatering system has a capacity of 5000 gpm. The mine is currently using about 1000 gpm. This would leave about 4000 gpm available for UNO. While the amount of water that would have to be pumped from the UNO excavations is unknown, based on previous mine experience it is estimated that a maximum capacity of 500 gpm will be required.

- Water treatment: The surface water treatment facility has a capacity of 4000 gpm. The mine is currently using about 1100 gpm normally and about 2000 gpm during spring runoff, leaving about 2000 gpm available for UNO. The estimated UNO need is 500 gpm.

- Compressed air: There are two 8000 cfm, one 6000 cfm, and one 1700 cfm compressors available as part of the mine compressed air system. The mine currently uses about 6000 cfm, leaving in excess of 16000 cfm available for UNO.

- Concrete batch plant: A concrete batch plant for mixing concrete and shotcrete that would be required during UNO construction is available. The batch plant has a capacity of 200 yd^3 per day, of which the mine is currently using about 60 yd^3 per day. About 140 yd^3 per day would be available to UNO.

- Rock conveyor system: The mine conveyor system for rock removal was designed for a capacity of 40,000 tons per day. The mine is currently using about 21,000 tons per day. The estimated maximum that would be required for mine production is 30,000 tons per day, leaving at least 10,000 tons per day available for UNO. During UNO construction, it is estimated that a capacity of 3,000 tons per day will be required.
- Office space: Office space in the main mine office building 60 ft by 60 ft in area will be immediately available to UNO.
- Outreach facilities: An area at the mine site about 4 acres in size is available for the construction of outreach facilities.

0.1.5 Summary

Considering primary factors such as geology, cost, quality, and environmental impact, the Henderson Mine is a strong competitor for siting UNO and other underground science experiments. Considering other important factors such as cooperation from mine ownership, accessibility, proximity to industry, technicians, and major academic institutions, Henderson becomes the preferred choice. When quality of life, educational, recreational, and cultural amenities are also considered, Henderson is a very attractive package.

With a minimum 5,000' (4,200 mwe) overburden at the proposed UNO excavation cavity, the Henderson Mine is deep enough to meet the low cosmic ray background levels required for UNO and most other proposed underground experiments, and deeper levels are relatively easily and affordably achievable. Preliminary estimates suggest that levels at 7,000' (6,000 mwe) can be reached with primary and secondary tunnels in less than a year for around $23M. Preliminary geological studies suggest that the rock at the proposed excavation site is likely to be Silver Plume granite, ideally suited to large cavity excavation.

As a recently upgraded modern mine, Henderson is safe and has the infrastructure and excess capacity to accommodate easily the additional excavation and infrastructure support required for UNO. Its main shaft is large enough (28' diameter) to accommodate sea containers, and it has in place - now - the necessary excess electrical power and water treatment capacity to meet the laboratory's needs. Furthermore, the efficiencies of its high capacity excavation and rock removal methods will save tens of millions of dollars in excavation costs, and the environmental impact is fully accommodated within Henderson's existing permits. When the mine ceases operations (estimated between 15-25 years), the conveyer tunnel will provide a convenient high capacity horizontal access as well.

The major local stakeholders are very supportive of this project. They see the economic, cultural, and educational advantages to becoming UNO's home. Phelps-Dodge, the parent company, owns all the land involved in the project. Though the legal relationship between the company and a national facility would need to be defined in detail, they have expressed a great willingness to pursue the initiative.

It is remarkable that, as one of the ten largest underground operating mines in the world, the Henderson Mine is located within minutes of an interstate highway and just an hour's drive from a major metropolitan area with its broad supporting base of technical industries, highly trained workforce, research universities, and a major international airport - not to mention four professional sports franchises. It is worth mentioning as well that seven major mountain and ski resorts are located within an hour of the mine.

Henderson Mine provides an historically unique opportunity for the nation to create - at relatively modest cost and in a highly desirable location - the major underground facility needed to address some of the deepest questions of contemporary physics.