HIGH ALTITUDE MINE WASTE REMEDIATION - IMPLEMENTATION OF THE IDARADO REMEDIAL ACTION PLAN[1]

by

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Abstract: The Idarado Mine in Colorado's San Juan Mountains includes 11 tailings areas, numerous waste rock dumps, and a large number of underground openings connected by over 100 miles of raises and drifts. The tailings and mine wastes were generated from different mining and milling operations between 1875 and 1978. The Idarado Remedial Action Plan (RAP) was an innovative 5-year program developed for remediating the impacts of historic mining activities in the San Miguel River and Red Mountain Creek drainages. The challenges during implementation included seasonal access limitations due to the high altitude construction areas, high volumes of runoff during snow melt, numerous abandoned underground openings and stoped-out veins, and high profile sites adjacent to busy jeep trails and a major ski resort town. Implementation of the RAP has included pioneering efforts in engineering design and construction of remedial measures. Innovative engineering designs included direct revegetation techniques for the stabilization of tailings piles, concrete cutoff walls and french drains to control subsurface flows, underground water controls that included pipelines, weeplines, and portal collection systems, and various underground structures to collect and divert subsurface flows often exceeding 2,000 gpm. Remote work locations have also required the use of innovative construction techniques such as heavy lift helicopters to move construction materials to mines above 10,000 feet. This paper describes the 5-year implementation program which has included over 1,000,000 cubic yards of tailing regrading, application of 5,000 tons of manure and 26,000 tons of limestone, and construction of over 10,000 feet of pipeline and approximately 45,000 feet of diversion channel.

Additional Key Words: Reclamation, Tailings, Source Control, Abandoned Mines, Direct Revegetation.

History of the Idarado Mine

The Idarado Mine is located high in the San Juan Mountains of southwestern Colorado between the San Miguel River and Uncompahgre River (or Red Mountain Creek) watersheds (see Figure 1). Idarado consists of a consolidation of several historic mining properties at high elevation including such famous old mines as the Smuggler, Tomboy and Black Bear, and newer developments at lower levels. The mining district includes some of the most famous gold-bearing quartz veins in the world including the Argentine, Smuggler-Union, Ajax, and Montana. The region is perhaps most famous for its fissure-type veins, some of which are traceable at the surface for several miles. The mines started out as gold and silver producers but as they were deepened they encountered sulphides of zinc, lead, and copper, making them primarily base metal producers.

In 1875, mining began on the Telluride side at the Smuggler in Marshall Basin. Like the Smuggler, most of the mines were located in rugged terrain at high elevations, between 9,000 and over 12,000 feet above sea level. They were virtually inaccessible by roads and so several miles of aerial tramways were eventually constructed to move supplies and men in and ore out. The Tomboy was located in 1880 in Savage Basin and mining at the Black Bear in Ingram Basin was started in 1894. The Smuggler, Tomboy, and Black Bear would later form the nucleus of Idarado.

The Idarado Mining Company was formed in 1939 to acquire properties on the Red Mountain side, including the Treasury Tunnel, Barstow and Black Bear mines. Idarado facilitated the reopening of the Black Bear Mine by extending the Treasury Tunnel over 7,000 feet. Meanwhile, Telluride Mines, Inc. was consolidating properties on the other side of the mountain. Telluride

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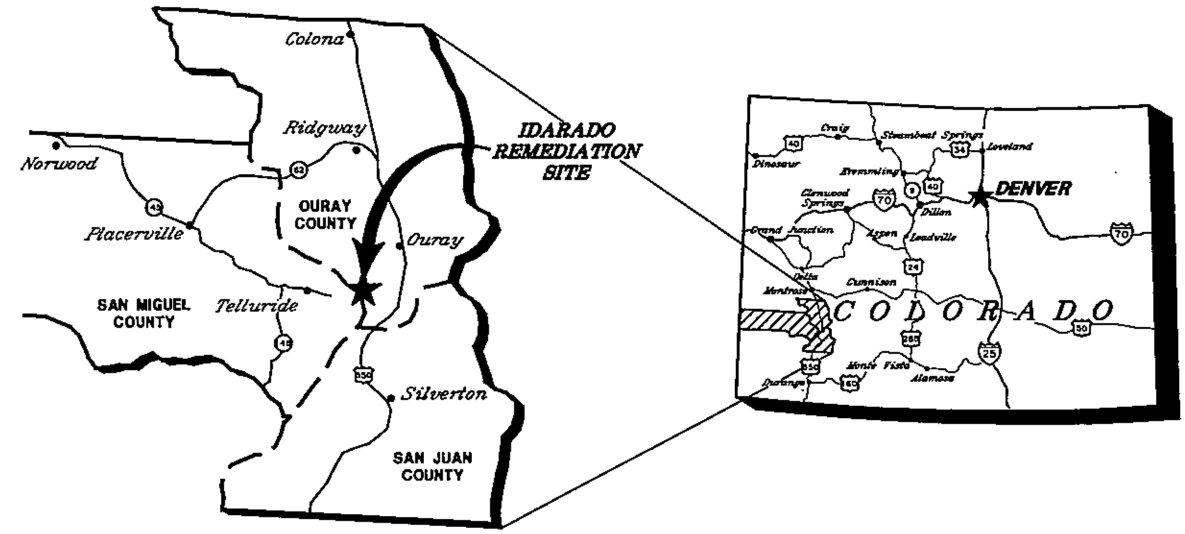
Figure 1 – General Location Map



Mines drove the Mill Level Tunnel to a point 9,500 feet from the portal and also constructed a major ore pass and master raise to the Penn Level, 1,200 feet above.

With the completion of these two tunnels, it was now possible for the two mines to transport ores to either Telluride Mine's Pandora mill or Idarado's Red Mountain mill (now only separated by a distance of 5½ miles) through the mountain. In May, 1953, Telluride Mines was purchased by Idarado. Soon after the acquisition, intensive underground development continued in order to consolidate more of the underground workings. The Mill and Meldrum levels were connected, and the Treasury Tunnel was extended to the northwest. Simultaneously, the Pandora mill and crushing plant were reconstructed, eventually resulting in the decommissioning of the Red Mountain mill in December, 1956. A 12,000 volt transmission line was also constructed through the mountain to supply power to Pandora. Eventually Idarado would have constructed over 80 miles of rail between Pandora and Red Mountain on 29 different levels.

Historic mining claims, primarily located at higher elevations, had produced an estimated 3,465,800 ounces of gold and 358,577,000 ounces of silver. In 1944, Idarado started mining lead, zinc, and copper for the war effort. In its 39 years of operation, Idarado produced 253,000 tons of lead, 395,000 tons of zinc, and 77,390 tons of copper, along with an additional 763,000 ounces of gold and 20,000,000 ounces of silver. The Idarado Mine closed on November 30, 1978 due to increased mining and processing costs, having mined an estimated 22,230,500 tons of ore from the mountain. Processing costs had increased largely because of shipping - copper concentrate went to a smelter in San Manuel, Arizona, zinc went to St. Joseph, Pennsylvania, and lead went to Trail, British Columbia.

Introduction

The remediation of the Idarado Mine was completed under a negotiated Consent Decree resulting from litigation under the State of Colorado CERCLA program. All work at the Idarado site was coordinated with and approved by the Colorado Department of Public Health and the Environment (CDPHE). In 1983, the Colorado Attorney General filed a CERCLA action against Idarado, a subsidiary of Newmont Gold Company, regarding the environmental consequences of historical mining in the area. Under the resulting Consent Decree, and in cooperation with local citizens and CDPHE, Idarado developed a Remedial Action Plan (RAP. The Idarado RAP, a 174-page document, was an innovative 5-year program (1993-7) developed for remediating the impacts of historic mining activities in the San Miguel River and Red Mountain Creek (Uncompahgre) drainages.

The primary objective of the RAP was to improve surface water quality, specifically by reducing levels of zinc, in the San Miguel River and Red Mountain Creek drainages. This objective would be achieved by implementing a variety of source control measures to isolate the mine waste material from contact with water. The methods of isolation varied depending upon the nature and location of the mine waste material, but generally involved stabilization, stormwater control, and sediment and erosion control.

In general, the source control methods described in the RAP included implementation of the following remedial measures:

- Removal and consolidation of miscellaneous (scattered) tailings and waste rock;
- Regrading of tailings piles and select waste rock dumps;
- Construction of diversion channels to intercept runon from upgradient watersheds and to collect runoff from reclaimed surfaces;
- Plugging of decants and underdrains;
- Implementation of direct revegetation on the regraded tailings pile surfaces;
- Placement of riprap and rock armoring for flood protection;
- Construction of rock buttresses to ensure stability;
- Construction of pipelines and weeplines to convey portal discharges away from mineralized areas;
- Construction of portal collection systems; and,
- Construction of mine diversions and sediment traps to control underground mine flows.

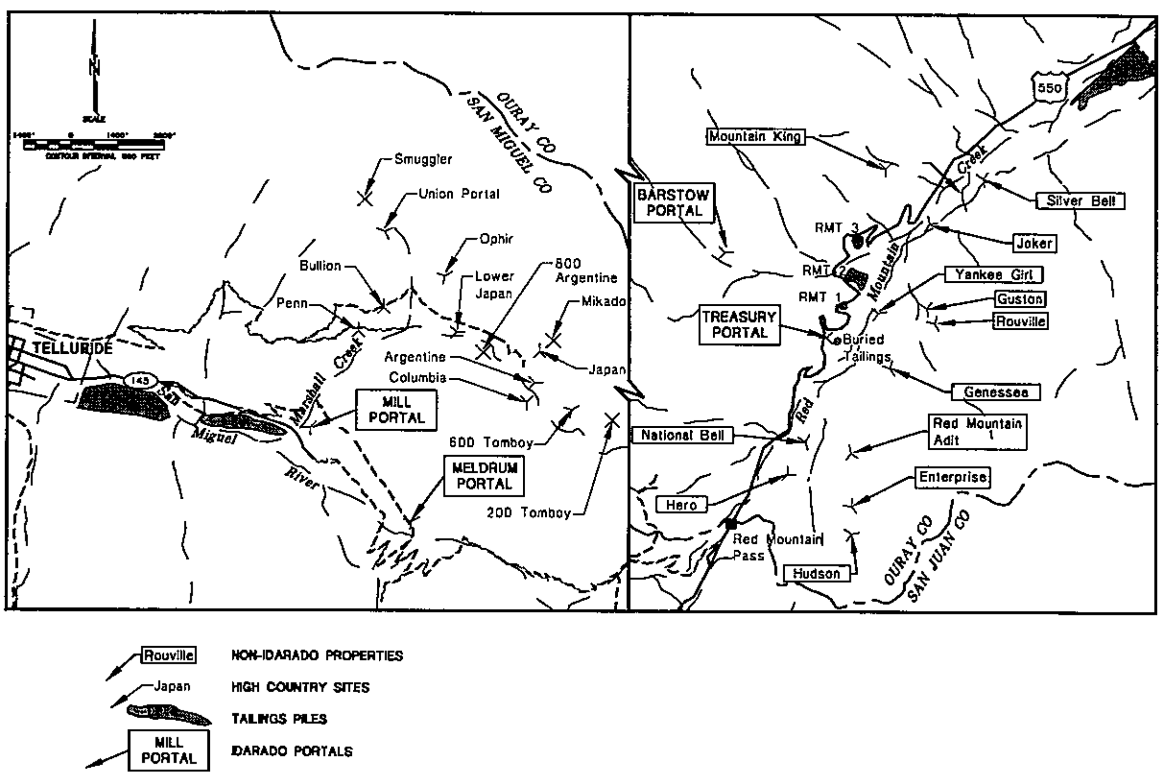
To ensure successful implementation of the RAP, Idarado formed a cohesive team of Colorado-based companies experienced in the area of mine remediation. An engineering consulting company, Montgomery Watson Mining Group (formerly TerraMatrix), was retained to complete engineering designs and perform construction oversight and management. Nielsons, Inc., an experienced remediation contractor, was hired to work alongside Idarado work crews to complete the construction elements.

Site Description

The Idarado Mine covers a surface area of approximately 16.5 square miles. The remediation sites were subdivided into four work areas across the entire Idarado property (see Figure 2). These areas included Telluride (sites at the end of Highway 145 Spur, approximately 1 mile east of town), the High Country (four drainage basins above the town of Telluride), Red Mountain (which is located approximately 12 miles south of Ouray), and the Underground Mine.

The remedial work areas at Telluride included 6 tailings piles and two mine portals. The six individual

Figure 2 – Site Location Map



tailings piles were built as two larger continuous impoundments in the San Miguel River valley. Telluride Tailings Piles 1 through 4 (TT1-4) included over 800,000 tons of tailings. TT1-4 was over 2,500 feet long, 450 feet wide, with a maximum height of 45 feet. Telluride Tailings Piles 5&6 (TT5&6) was significantly larger than TT1-4. It included over 11,000,000 tons of tailings (8,100,000 cubic yards). TT5&6 was over 3,500 feet long, up to 1,000 feet wide, with a maximum height of 100 feet. The two mine portals included the Mill Level Portal (the 2900 level, the lowest level of the underground mine) and the Meldrum Portal (the 2000 level).

The remedial work areas in the High Country included historic mine portals, waste rock piles, stream channels, and mine inflow areas over open veins and shafts. The High Country sites were all located above an elevation of 10,000 feet in four drainage basins, Marshall, Middle, Savage and Ingram. There were over 20 waste rock piles and 8 historic mines that were specified in the RAP for various remediation activities. In addition, six areas required remediation to prevent surface flows from inflowing into the underground workings.

The remedial work areas at Red Mountain included 5 tailings impoundments constructed in the Red Mountain Creek valley and 14 mine portals. The 5 tailings impoundments were identified as Buried Tailings and Red Mountain Tailings Pile 1 (RMT1), 2, 3, and 4. The Red Mountain Buried Tailings included over 150,000 tons of tailings. RMT1, RMT2, RMT3, and RMT4 included tailings tonnages of 150,000, 400,000, 100,000, and 1,200,000, respectively. Maximum heights for RMT1, RMT2, RMT3, and RMT4 ranged from 10 to 80 feet, and the surface area for these piles totaled over 35 acres. Two mine portals owned by Idarado were also designated as remedial sites. These portals included the Treasury Portal (or 1200 level) and the Barstow (at approximately the 400 level). In addition, 12 mining properties at Red Mountain never owned or operated by Idarado were designated in the RAP for remediation. These non-Idarado properties included such famous mines as the Guston, Yankee Girl, and National Bell, and comprised of numerous waste rock piles, shafts, adits, and portals.

The remedial work areas in the Underground Mine included approximately 30 miles of raises, drifts, and tunnels from the 100 miles of workings that made up the Idarado Mine. Underground remedial work areas included drifts and raises where typical flows measured during the Spring months were as high as 2,000 gallons per minute (gpm).

Topographic Setting and Drainage Patterns

The Mill Level Portal is located at Pandora at the end of Highway 145 Spur approximately 1 mile east of Telluride at an elevation of 9,062 feet above sea level. The Treasury Portal is located at Red Mountain below Highway 550 approximately 12 miles south of Ouray at an elevation of 10,620 feet above sea level (see Figure 2). The distance from portal to portal via the mine workings is 5½ miles.

The terrain around Telluride and Red Mountain is extremely rugged. This area of the San Juan Mountains is surrounded by the highest concentration of 14,000-foot peaks in North America. At these high elevations, the winter snowpack commonly exceeds depths of 20 feet, and snow slides are the norm rather than the exception. Surface runoff leaves the High Country in Marshall Creek and enters the San Miguel River east of TT1. Ingram Basin also drains into the San Miguel River east of the Telluride tailings piles. Underground water goes via a system of interconnected ore passes, raises, and drifts. Water then flows out through three main portals, the Treasury Tunnel (1200 Level), Meldrum Tunnel (2000 Level), and Mill Tunnel (2900 Level).

Remedial Measures

Rather than including detailed final designs, the RAP included general specification for the designs, such as channel capacities, tailings impoundment regrading requirements, and portal closure techniques. Based on the technical specifications included in the RAP, a set of Performance Demonstration Criteria was included that described as-built measurements and survey requirements that would be used to determine if the specifications had been meet. Based on the results of the Performance Demonstration Criteria, a Completion Determination for compliance with the RAP specifications could be made.

Tailings Piles

The intent of the tailings pile remediation effort was to provide a final condition for the impoundments that was erosionally and geotechnically stable, had runon and runoff control, was stabilized against flood events in adjacent streams and could sustain vegetation on its surface. The stabilization of the tailings pile included regrading of the impoundments, construction of runon and runoff diversion channels, armoring of the side slopes, and incorporation of amendments into the surface of the regraded tailings to facilitate direct revegetation of the surface. All decants and underdrains were filled prior to commencing regrading activities.

For the tailings pile regrading, the RAP specification required that the side slopes be graded to 3 horizontal (H): 1 vertical (V) and the top surface sloped away from the crest at between 0.5 and 2.0 percent. The grading requirements were based on meeting the required factors of safety for the side slopes, 1.5 for static and 1.2 for pseudostatic, and providing positive drainage from the top surface to the diversion channels. Saturated fine grained tailings (or slimes) were located near the embankment of one impoundment where the toe was adjacent to a river. Therefore, a rock buttress with a 2H:1V slope was constructed to stabilize the critical section against any potential instability.

Direct revegetation of the side slopes and top surfaces of the tailings piles followed systematic testing of representative tailings samples. The revegetation program included the application of amendments, fertilizer, and a seed mix of up to 14 forbs and grasses. In accordance with the RAP, a grid was set up for representative sampling from one-acre cells. The tailings were tested for pH and acid generating potential to provide an estimate for the amount of lime and limestone required for neutralizing the tailings. Limestone was applied at a minimum rate of 200 tons/acre. Other amendments included hay or straw applied at 20 tons/acre and manure applied at 40 dry tons/acre. Following the tilling of amendments into the top 18 inches of the tailings surface, fertilizer was applied at a rate of 50 lbs of nitrogen per acre, 253 lbs of phosphorus per acre, and 80 lbs of potassium per acre. Finally, a seed mix was added to the tailings at between 36 and 37 lbs. per acre. Grasses included slender wheatgrass, smooth and mountain brome, orchard grass, hard fescue, common timothy, and Canada and Kentucky bluegrass. Forbs include cicer milkvetch, Lewis flax, alfalfa, sainfoin, Rocky Mountain penstemon, red clover and western yarrow.

In addition, the RAP specified that two diversion channels be constructed along the upgradient perimeter of each tailings pile. The tailings runoff channel, or TRC, was designed to collect runoff from the reclaimed top surface; the watershed interceptor channel, or WIC, was designed to collect runon from the watershed above the pile. Both channels were designed to discharge at the same point. The design of the channels included a 4-inch deep gravel bed underneath a 4-inch thick concrete lined trapezoidal channel. A 10-foot wide rock apron was also designed along the inside of the TRC to dissipate the energy of stormwater runoff. Diversion outlet aprons consisting of 8-inch grouted riprap were constructed at the discharge points of the TRC and WIC. Finally, interceptor rock aprons were constructed alongside the WIC wherever a natural drainage discharged directly onto the tailings pile to dissipate the energy of stormwater runon.

The majority of the lined diversion channels were lined with concrete. Two methods of concrete placement were used for construction of these channels. One method utilized a Trencor power trencher machine and a power curber with a modified float. Both machines operated off a stringline to establish the grade of the channels. The other method utilized screed rails and a hand pulled screed. The method of concrete placement depended on equipment access to the site. The trencher and curber were used primarily on the tailings impoundments and the screed placement method was used on the portal and High Country channels.

Figure 3 provides a general schematic of the remedial measures completed at the tailings piles.

Waste Rock Piles

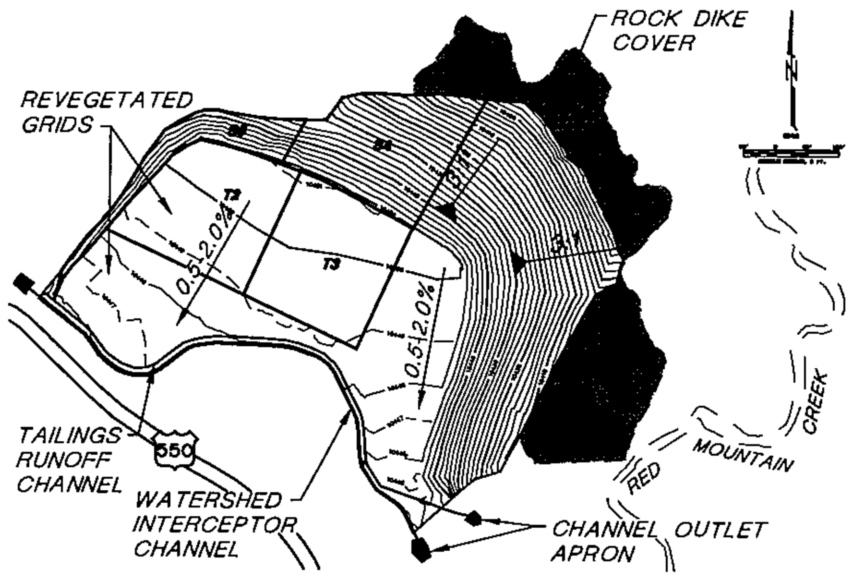
Remediation of waste rock piles included diversion channels to limit surface run-on, pipelines and weeplines to convey portal discharges, cutoff trenches to intercept groundwater and limited waste rock consolidation and capping to prevent active erosion. The primary remediation goals for waste rock included diversion of runon around the waste rock pile to prevent water from flowing across exposed minerals, and management of any portal discharge, that may be already potentially impacted from highly mineralized areas underground. The information that the RAP presented for waste rock remediation work included a general alignment and capacity of the diversion channels, basic waste rock pile regrading requirements, and a management method for any portal discharge from the workings.

Figure 4 provides a general schematic of the remedial measures considered for implementation at the waste rock piles.

Mine Portals

Discharges from the mine portals were typically collected in either a pipeline or diversion channel to convey the water away from adjacent waste rock. The portal discharge was conveyed directly into a natural drainage, to infiltration lagoons, or conveyed to

Figure 3 – Tailings Pile Source Control Measures

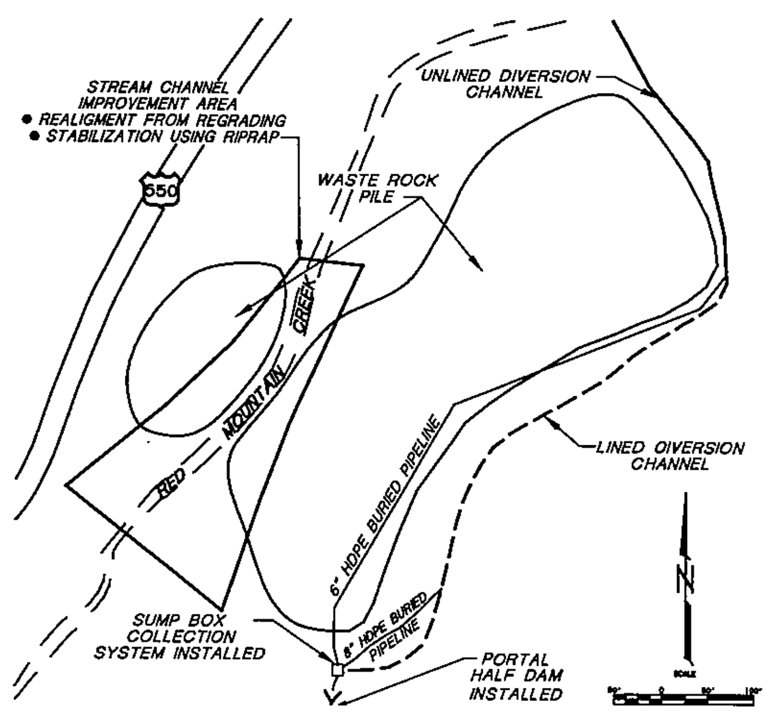


a weepline. The weeplines were similar to a septic leach field intended to allow infiltration of the portal discharge into the subsurface. The portal management of the water included either construction of a sump box collection system that would convey the portal flow to a surface management system or a dam to back the water up into the mine workings where the discharge could be better managed underground. Remediation at other high altitude mine sites included the remediation of existing stream courses and the construction of surface water diversions to reduce inflow into the underground mine workings.

Underground Mine

Since a large amount of snowmelt and other

Figure 4 – Waste Rock Pile Source Control Measures



surface water drains through the underground openings, the RAP specified that structures should be installed underground to divert water and better control sediment. In addition, the RAP specified that Idarado evaluate whether additional remedial measures could be constructed in areas where access could be provided through reasonable renovation of the workings.

Mine diversions included collection dams, half-dams, and portal plugs behind which water would collect and be diverted away from mineralized areas using a system of pipes or sill ditches. The collection dams were designed to collect flow from a sill ditch and divert it into a pipe. Half-dams were constructed across the full width of the drift to also divert the flow into a pipe. Half-dams were typically 3-feet tall and allowed for a greater storage capacity during high flow times. Portal plugs were required at four mines (Union, Penn, Bullion, and Ophir). The plugs were designed to prevent discharges from the portal thereby causing water to back up and travel down known pathways in the mine for collection from a lower level. Finally, sediment traps were required to reduce suspended solids in the Mill and Meldrum portal discharges.

All underground structures were constructed with reinforced concrete and located where there was adequate structural confinement and the best local rock quality. The RAP required that the structures be constructed on competent ground. Preparation of the surrounding rock to be used at the concrete-rock interface included removal of loose material and excavation of a key in the ribs into which rebar was set to tie the concrete to the surrounding rock.

Remedial Construction

1978-1992

Following closure of the mine in 1978 and prior to commencing RAP construction in 1993, Idarado completed a series of remediation activities both in the underground mine and on the surface.

During remedial construction activities in the underground mine workings, it was necessary for Idarado to secure bad ground along drifts and raises by placing ground support structures such as steel and timber sets, and gunnite to prevent air slacking. The majority of the renovation was completed for the mine areas that were previously inaccessible. Renovated drifts included 1,500 feet on the 1700 Argentine (Penn Level), 1,000 feet on the 2000 Argentine, and 1,000 feet on the 300 and 600 Black Bear levels. Renovated raises included the 42 Argentine raise between the 1700 (Penn) level and the 2000 level and the Black Bear raise between the 100 level (the highest level in the Idarado Mine) and the 600 level.

Surface remediation following mine closure included stabilization of the tailings impoundments and on going maintenance of surface structures. To prevent wind erosion of the tailings, Idarado implemented procedures to stabilize the Telluride tailings impoundments through establishing vegetation on the surface and constructing a sprinkler system to wet the tailings surface. At RMT1, the tailings pile was regraded and a temporary channel constructed across the top surface to provide a drainage channel for the surface runoff. Due to the limited budget for an inactive mine site, the work done during this period was primarily for maintenance purposes; however, the mine personnel used this time and the increasing environmental awareness to observe potential environmental impact from the mine and consider what measures would be effective in reducing these impacts.

In addition, between 1989 and 1992, Idarado completed a preliminary field investigation program to characterize the tailings impoundments and other materials available onsite for use as potential borrow sources.

1993-1997 (the RAP years)

The RAP included guidelines for completing certain remedial tasks within a given timeframe. In order to obtain maximum benefit from the short construction season, it was necessary to establish an implementable work plan early on so that work tasks could be prioritized. A detailed construction sequence was developed for the work areas and a competitive bid process was initiated to assist Idarado with the remediation. Idarado selected Nielsons to perform the work primarily due to their extensive experience in environmental remediation and ability to mobilize equipment quickly.

Tailings Piles - Regrading Techniques. Based on their experience with the tailings material, Idarado had concerns about what type of equipment would work for regrading the large piles. Similar upstream tailings piles in the area had used trucks and excavators to improve material handling and to develop a workable surface. Based on the excavation of test pits in the Fall of 1994, it was decided to regrade a small area of TT5&6 using scrapers to evaluate their applicability in regrading the tailings. For the test excavation of the tailings, two 631 Caterpillar scrapers and a D-8 push dozer were used. The one week regrading test was extremely successful and formed the basis for the development of all future tailings regrading plans. Based on detailed surveying of both the cut and fill areas it was determined that the tailings material experienced a "shrinkage" of approximately 21 percent.

As the scraper regrading work began soft conditions in the fill areas made it clear that special considerations would need to be taken to ensure that operational problems with the scrapers did not develop. Various operational techniques were developed including increased lift thicknesses across unstable soft areas, sequencing of fill placement, and geotextile placement to bridge soft areas. One technique used "causeways" across the fill areas approximately 200 feet in advance of the previous scraper pass. By allowing the scrapers to dump on the perimeter and spreading the fill from all sides of the fill area, the mud wave size and location was more easily managed. In some locations, the amount of fill over the soft areas was small such that the geotextile bridging technique would work. In these areas a separation layer of geotextile was placed to assist in bridging the areas and provide a more stable working surface.

As the regrading proceeded, periodic surveys of the cut and fill areas were made to track the material balance in order to ensure that the overall regrading would balance and the required grades meet RAP requirements with a minimum of material handling. At approximately the one-third point on the regrading, the results of the surveys indicated that the actual shrinkage from the cut to the fill was about 26 percent so that the original fill plans for one pile would not meet RAP requirements without additional cut. An updated grading plan was prepared that increased the slope in the fill area, to near the maximum allowable 2 percent, to reduce the total amount of fill required. It was decided that the additional cut would be made from the slope rather than from the top surface due to the near-surface location of the soft slimes material.

<u>Tailings Piles - Seep Concerns</u>. Several seeps had been observed historically along the side slope of RMT2. These seeps raised several concerns regarding stability, constructability, and potential environmental impact. Further, four standpipe piezometers had been installed in the pile and had consistently shown a relatively high phreatic surface. As a result of these current concerns, a plan was developed to both reduce infiltration into the tailings and provide a stable working surface for the diversion channels. In order to reduce the amount of subsurface flow into the pile from the watershed above and allow for ease of construction of the concrete diversion channels, a subsurface cutoff trench was constructed during the regrading phase. The trench was located along the uphill perimeter of the pile directly under the proposed alignment of the two diversion channels. The trench included a low permeability (30-mil PVC) liner on the slope contacting the tailings, a 12 oz/yd^2 nonwoven wrapped geotextile filter, an 18-inch ADS drain pipe, 1½-inch washed drainage gravel, and 4-inch minus rock for use as a subgrade layer below the proposed channels. Collection of subsurface flows in the cutoff trench and preparation of a free draining subgrade layer were critical for the successful completion of construction activities one year later.

<u>Tailings Piles - Stability</u>. A review of available geotechnical data and a stability analysis was completed for each tailings pile. Stability concerns at three tailings piles were related to the presence of weaker slimes material near the proposed 3H:1V cut face. A description of the stability concern and the method in which it was addressed for each of these tailings pile is presented below.

At TT4, a pocket of slimes had been identified near the 3H:1V cut slope. TT4 was an upstream constructed impoundment where the tailings were spigoted from the perimeter of the impoundment with the sand fraction settling out near the perimeter and the finer slimes settling at the interior of the impoundment. Apparently during deposition, operation of the spigots allowed a large pocket of the slimes material to deposit near the perimeter. This soft pocket of slimes would have been close enough to the cut face of the proposed 3H:1V slope to create potential long-term instability. TT4 is located adjacent to the San Miguel River such that the toe of the slope could not be extended outward to avoid cutting the material near the slimes. Therefore, based on the space limitations and stability requirements a rock buttress was designed for this area that would allow the lower portion of the slope to be buttressed with rock at a slope of 2H:1V and allow the required long term factors of safety to be achieved.

The slope stability review for RMT2 also indicated that the presence of slimes near the face of the embankment could cause problems. In addition, discussions with mine personnel indicated that in 1946, during active operation of the facility, an embankment failure had occurred. RMT2 was also an upstream constructed impoundment, and included a series of rock starter dikes constructed around the perimeter of the pile. Additional requirements of the RAP included cleaning the tailings that had migrated down over these rock starter dikes and covering these areas with additional rock. As previously discussed, seepage through the rock dike areas and high water levels within the impoundment were a stability concern. The area with the largest amount of seepage was also the area where the impoundment had historically failed and had a large accumulation of tailings that needed to be removed.

To further characterize the area of concern, a cone penetrometer testing program was carried out to identify the location and characterize the weak slime zones. Several piezometers had been completed in this area during previous geotechnical investigation work and a program of daily water level measurements was required prior to and during construction work. Based on the additional data, a removal and monitoring plan was developed for removal of the tailings material over the rock dike area. The monitoring plan included both the daily water level recording and surveying of monuments to measure slope movements. These monuments were surveyed at the beginning and the end of each day to determine if the removal of the material was causing any movement in the rock dike. The removal of the tailings was completed without incident and a 2H:1V rock buttress was constructed using slide rock from a nearby source to further stabilize this portion of the rock dike. The area continued to seep following removal of the tailings material. A geotextile was included at the contact between the existing rock dike and the buttress material to prevent the piping of any material from the tailings impoundment that could lead to future stability problems. The regrading of the tailings above the 2H:1V rock slope was completed during the following construction season without problems.

RMT4 was also an upstream constructed tailings impoundment. It was constructed by building a series of alluvial phases using the upstream method, with an average outslope of approximately 1.3H:1V. Because of the stability provided by the alluvial embankment raises, the tailings were not necessarily spigoted from the embankment, so that significant areas of slimes were present close to the embankment. Following a review of as-built drawings showing the geometry of the embankment raises, it was apparent that a 3H:1V slope would cut through the embankment thereby compromising its structural integrity.

As a result of both stability and revegetation concerns at RMT4, the requirements of the RAP were changed to allow an alternative side slope configuration. The alternative included removing wind blown tailings from the slope and placement of a minimum of three feet of rock cover material. Slide rock from an onsite borrow area met the stability and erosional requirements for this cover layer.

Tailings Piles - Revegetation. The RAP required that the regraded surface of the tailings piles be directly revegetated following application of amendments necessary to develop a suitable growth matrix from the tailings material. As described above, the RAP required that lime should be added to the tailings to raise the pH to 7.0. Additional RAP amendment application rates included a minimum of 30 tons/acre of limestone, 50 dry tons/acre manure and 40 tons/acre of hay or straw. A seed mixture and application rate of native species was specified for the tailings piles and a 2 tons/acre mulch of hay or straw was required following seeding. Finally, following the seeding and mulching, inorganic fertilizer was added to the tailings.

Idarado decided that more limestone would be added to offset the entire acid generating potential of the top eighteen inches of tailings material. Therefore, based on the tailings testing results, the minimum amount of limestone that would be applied was increased to 200 tons/acre. By ignoring the presence of any neutralizing potential in the tailings, and using a 200 tons/acre minimum application rate, Idarado anticipated this conservative approach would prevent "hot spots", or localized areas that could potentially become acidic.

The addition and incorporation of the amendments was performed using standard agricultural equipment. The placement and tilling on the 3H:1V side slopes required special operational techniques. Manure was applied with an agricultural manure spreader pulled by either a rubber tracked or four-wheel-drive agricultural tractor. For application on the side slopes the equipment worked from the bottom of the slope to the top traveling perpendicular to the slope. On the top surfaces the limestone was applied with a fertilizer truck equipped with a broadcast spreader. On the side slopes this truck was either towed up the slope during amendment application or the manure spreader was used as it was for manure application. 1,000-lb straw bales and 1,600-lb hay bales were applied using a large rotating drum bale processor. To allow the bale processor to operate on the side slopes the axles were extended to increase the stability of the equipment. Following application of each amendment the material was tilled into the top 18-inches using an agricultural rotary tiller. The seed mixture was drill seeded into the amended tailings with a revegetation seed drill. Following drill seeding, the mulch hay or straw was applied with the bale processor and crimped with a revegetation crimp disc. Quantities of amendments applied for the direct revegetation of the tailings are summarized below in Table 1.

To help establish the vegetation, the RAP allowed Idarado to irrigate as they deemed necessary during the first two summers following completion. During years three and four following revegetation, Idarado was allowed to irrigate the vegetated surfaces to make up the difference between average precipitation and the amount the site had received at any given time. For the smaller tailings piles, Idarado installed fixed set sprinkler irrigation systems. Due to the amount of material that would be required for fixed set sprinkler systems on the larger tailings piles, large water reel sprinkler systems were used.

High Country. Several source control measures were constructed in the High Country. These included the following major elements:

- 16 diversion channels to divert stormwater runon around waste rock piles;
- 5 stream channel improvements to protect waste rock against erosional instability and sediment transport;
- 8 portal remediations that included either portal plugs or low head dams and pipeline collection systems; and,
- 6 inflow diversion channels to prevent stormwater from infiltrating into the underground workings via open stopes and veins.

Since there was limited access to much of the work areas in the High Country, a Sikorsky helicopter was used to airlift aggregate and concrete materials. While conventional truck hauling was possible, the treacherous road conditions and a limited capacity to support large haul trucks caused significant delays, safety hazards, and truck damage. By airlifting the materials into the work sites, what would have taken two months and caused serious delays in the construction schedule, was completed in three days. The labor and equipment savings balanced the high cost of the helicopter and the project benefited from the reduced risk to personnel and the expedited construction schedule.

Remedial activities in the High Country presented unique challenges in high altitude construction. The local climatic and ground conditions demanded flexibility in the design and construction of many of the remedial structures. Accurate survey control had to be established from the Telluride and Red Mountain bases. The ability to mobilize construction equipment quickly and use remote power sources was also critical to successfully completing the work tasks. And finally, the construction of temporary man-camps in the high altitude basins allowed for longer work days and maximum use of the short construction seasons.

Idarado Red Mountain Portals. The Idarado mine workings included two portals in the Red Mountain Creek drainage, the Treasury Tunnel and the Barstow Mine. During operations, the Treasury Tunnel was the primary access from the Red Mountain side to the underground workings, providing access to the 1200 Level of the mine. The Barstow portal was associated with an early mining operation that later tied into the Treasury Tunnel. The Treasury Tunnel had a portal discharge of approximately 12 gpm. The Barstow portal discharge had been historically contacting mine waste at the site.

The remediation for the portal flow from the Treasury Tunnel included construction of a portal

Table 1 - Tailings Pile Amendment Quantities

Tailings Pile	Amendment Quantities			
	Lime (lbs)	**Limestone (tons)**	**Manure (tons)**	**Hay/Straw (tons)**
Telluride				
TT1-4	-	2,034	805	424
TT5&6	13,025	15,279	3,977	1,434
Red Mountain				
Buried Tailings	-	-	-	-
RMT1	3,650	81	40	25
RMT2	30,150	1,660	328	176
RMT3	2,700	1,095	167	81
RMT4	20,502	5,597	972	527
TOTALS	70,027	25,746	6,289	2,667

collection system and pipeline to convey the flow to a weepline. The weepline infiltrates the portal water into the subsurface where the metals are adsorbed to subsurface materials. The only nearby area identified with adequate soil for the Treasury Tunnel weepline was a groundwater discharge point during spring runoff which was therefore unsatisfactory for the weepline. Consequently, Idarado constructed a pump-back system to transfer the Treasury Tunnel flows to the Telluride workings where the flows could be more effectively managed.

Similarly, at the Barstow portal a plug was constructed to backup the underground water for diversion to the Treasury portals. The Barstow portal was located under the toe of the main waste rock dump which had created poor rock mass along the drift since it had last been accessed. Therefore, the portal plug at the Barstow had to be constructed in competent wall rock approximately 200 feet back from the portal. The small amount of water that still discharged downgradient of the plug was then conveyed through a weepline beyond the waste dumps. Additional surface water controls including lined and unlined diversion channels were also constructed at the Barstow to convey surface water around the surface mine wastes.

Non-Idarado Red Mountain Properties. The scope of work at the Non-Idarado Red Mountain Properties included the following main elements:

- Construction of lined and unlined run-on diversion channels around waste rock piles;
- Installation of portal collection systems and discharge pipelines to convey portal water away from mine wastes;
- Construction of unlined infiltration channels to allow infiltration of portal waters to native ground;
- Removal of waste rock, realignment and stabilization of stream channels; and,
- Installation of culverts to carry stormwater under active jeep trails.

In general, the portal collection systems consisted of a concrete lined sump box or reinforced concrete half-dam. The sump box was installed outside the portal. Measures taken to facilitate drainage of the portal water into the sump box usually included the installation of a pipeline and area regrading. The half-dam portal collection system was usually installed up to 100 feet inside the portal in an area of competent ground. A pipeline then conveyed water collected by the portal collection system to a lined or unlined diversion channel to allow infiltration into native ground.

Stream channel improvements were completed to ensure adjacent waste rock was not eroded during the 100-year flood event. Where the toe of adjacent waste rock piles could not be set back from the flood plain without significant regrading, the waste rock was stabilized with a reinforced shotcrete lining.

Underground Mine. Twenty sediment traps have been constructed along drifts on the 1200 and 2900 levels where the highest flows have been historical observed. The sediment traps have been constructed in groups of 6 or 8 and intercept water coming out of the Black Bear Raise, 13 Argentine Raise, and 48 Argentine Ore Pass. The sediment traps are generally 250 feet (or one block) apart. A typical sediment trap design is included on Figure 5. In general, the sediment traps are approximately 3 feet high, 8 inches thick, and 8 to 12 feet wide (depending on the width of the drift) and constructed with reinforced concrete. The horizontal rebar is epoxy grouted into drillholes in the ribs, set between the forms, and welded to a steel channel into which 12-inch timbers are placed. The timber inserts are required over the tracks to provide access for the rail equipment for maintenance and cleaning of sediment traps located further up the drift. Sediment traps collect water flowing down the 2913 Argentine Raise, 2948 Argentine Ore Pass and the 1200 Level Tomboy Raise.

Seven collection dams were constructed along drifts on the 1200, 2000, 2400, and 2900 levels to collect water conveyed in the sill ditches. In general, the collection dams are 1 to 2 feet high, 3 to 5 feet wide, and approximately 8 inches thick. Prior to construction the floor of the drift across the alignment of the sill ditch was cleaned to solid rock and the collection dam was keyed into the adjacent rib.

Conclusions

All remedial activities specified in the Idarado RAP are based on classic source control theory. The remediated sites are now in the post construction monitoring phase. With Idarado assistance, the system is being given 5 years to heal itself until 2001. At that time Idarado will commence weekly sampling to check its compliance with the Consent Decree. This 10-year evaluation period will end in 2011, at which time the revegetated tailings will grow unassisted.

The challenges during implementation of the RAP included seasonal access limitations due to the high altitude construction areas, high volumes of runoff during snow melt, numerous abandoned underground openings, and high profile sites adjacent to busy jeep trails and a major ski resort town. These limitations required careful planning in order to benefit the most from the short construction seasons and the difficult site conditions.

Remediation of the Idarado Mine was the first state-run mine Superfund site completed in the U.S. Many of the remedial elements in the 5-year program were completed ahead of schedule. The successful implementation of the Idarado RAP has become a model environmental remediation project, completed in close cooperation with state agencies and local citizen groups. In 1997, the Associated General Contractors presented the Build America Award to Nielsons for their successful construction efforts at the site.

References

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Figure 5 – Underground Source Control – Sediment Trap