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Burlington Mine Site Voluntary Cleanup: An Ecologically-Based Approach to Mine Site Remediation

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Introduction

Photo 1: Burlington Mine circa 1962, courtesy of Denver Public Library

The Burlington Mine is an inactive mine located in the foothills of Boulder County, near the Town of Jamestown, Colorado. While in operation from 1920 to 1973, the Burlington Mine was part of the chief fluorspar-producing district for the western United States. Photograph 1 shows a historical photograph of the mine site circa 1962. The Burlington remediation was conducted under the Colorado Department of Public Health and Environment's Voluntary

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Cleanup (VCUP) program.

Goals of the remediation were to improve water quality in receiving streams, limit the potential for future subsidence, reduce onsite safety hazards and liability, and to achieve these goals using an ecologically-based approach. The Burlington design incorporated many innovative techniques that exceeded basic requirements, met multiple project goals, and still accommodated the abundant constraints and challenges at the mine site. Innovations included measures to address drainage issues at pit closures and unique techniques to imitate natural channel form and function, restore riparian habitat, and enhance habitat value on the site for future wildlife usage.

The ecologically-based approach resulted in more natural and functional systems that help soften the harsh aesthetics of the old mine site and improve wildlife habitat. In regards to site drainage, these are important improvements over more traditional mine site remediation, which has always addressed safe conveyance of onsite water, but not necessarily how to restore natural form and function or how to use the water to maximize habitat value for wildlife.

Water Quality Improvement

The goal of water quality improvement was addressed through a combination of diverse treatments, each of which served to reduce the interaction of surface and ground-water with the contaminated mine waste materials and underground mine workings located onsite.

Sitewide Treatments

Activities to correct sitewide surface and groundwater interactions included surficial waste rock consolidation, subsidence pit fill and mounding, soil amendments and topdressing, and revegetation with native species. The waste rock consolidation reduced the footprint of contaminated materials onsite, which reduced the area of potential contact and interaction.

Under existing conditions, the subsidence pits were providing direct flow paths into the mine workings. Of particular concern was the pit that intercepted Balarat Gulch, an intermittent drainage that drains to Little James Creek and ultimately to Left Hand Creek -- see photograph 2. Backfilling this pit was the first step in eliminating the direct flow path for the gulch into the mine workings. Final grading included substantial mounding over the backfilled pits to create a minimum two percent slope. The positive slope created by the mounding discourages infiltration -- and potential contact with mine workings -- by promoting runoff. In

anticipation of backfill settling, the area was overmounded by a minimum of 4 feet.

Photo 2: Direct flow path of Balarat Gulch into mine workings under existing conditions

Soil amendment included an agricultural lime application to neutralize the acid generation potential of the waste rock. All areas slated for revegetation were capped with a native soil layer and covered with compost. These topdressing layers serve two purposes: 1) they create a physical barrier to precipitation contacting the potentially acid generating materials below and 2) they provide a suitable growth medium for the revegetation effort. The physical barrier is actually a second level of protection against acid mine drainage generation since the waste rock was neutralized by the lime treatment. Revegetation helped stabilize the site and promote evapotranspiration and interception of precipitation over infiltration.

Balarat Gulch Treatments

Activities to correct the surface and groundwater interactions associated with Balarat Gulch included construction of a diversion channel that realigned the drainage to avoid mine workings and control of subsurface flows.

A projection to ground surface, created from 3-D mine mapping developed for the site, was used to identify the optimal centerline location and inverts for the diversion channel. The realignment routes flows to the east of the old subsidence areas. The diversion channel was sized to contain the 100-year storm event (plus 20 percent) within the protected main channel banks. The 100-year design reasonably protects against surface water re-accessing the mine workings by overflowing the diversion channel.

The critical upper reach of the diversion channel, where the channel makes a sharp bend away from its historic path, was lined with a PVC

liner to force water to stay in the channel and further reduce the potential for piping failure behind the channel's boulder wall bank protection. The two lower reaches of the diversion channel were left unlined to allow hillslope groundwater to access the new channel, rather than being forced underneath where it could potentially reach the underground mine workings.

While the diversion channel adequately rerouted surface flows in the gulch, a substantial portion of the total flow was being conveyed below the surface through the alluvium and along the bedrock contact. This subsurface flow had to be intercepted along with surface flows to successfully prevent water reaching the mine workings. A primary alluvial water control structure, extending down to bedrock, was installed at the top of the diversion channel. Depth to bedrock was determined by a geotechnical drilling program.

Two main components comprised the alluvial control structure -- a curtain drain and an impermeable liner. The curtain drain was constructed of prefabricated drainage panels with perforated PVC pipe threaded through bottom sleeves. The drain conveys the intercepted water. The impermeable lining traps the intercepted water, preventing it from bypassing the structure and forcing it into the curtain drain system.

As a secondary control, a scavenger drain installed to protect the pit closures was located where it could capture any water not intercepted by the upslope primary control. The scavenger drain also captures local groundwater flowing toward the closed features.

The combination of rerouting flows, pit backfill, and subsurface water control provides solid protection against flows re-accessing the mine workings. By preventing contact with the workings, cleaner water is delivered downstream.

Erosion and Sedimentation Controls

Additional measures were implemented to control erosion and sedimentation at the site long-term. Site grading and drainage included construction of a surface water control channel network, which conveys runoff through the site in a controlled manner and prevents the formation of rills or gullies to minimize sediment entrainment. Construction best management practices (BMPs) were employed to provide interim protection until vegetation becomes fully established at the site.

The sitewide revegetation also assists with erosion and sediment control. Vegetation stabilizes the soil, decreasing erosion from stormwater runoff.

Site grading followed a maximum 3H:1V slope wherever possible to assist the revegetation efforts and prevent excessive runoff velocities.

Reduction of Future Subsidence Potential

The Burlington Mine site has experienced consistent subsidence for at least 30 years. A beneficial side effect of the aforementioned water quality improvement activities is the notable reduction of future subsidence potential. The closure of shafts and subsidence areas combined with the realignment of Balarat Gulch away from the mine workings will inherently reduce the future risk of subsidence in the areas historically plagued with this problem. Similarly, by controlling and intercepting subsurface flows that would otherwise access the closed mine features, the water quality improvements mitigate the risk of future subsidence on the site.

Ecologically-based Approach

Methods for incorporating natural form and function and enhancing wildlife habitat were utilized in all feasible aspects of the remediation. The most notable features are the bed and bank treatments for the diversion channel, use of natural materials for all visible structures, waterfowl protection measures, and sitewide revegetation with native species.

Channel Bed and Bank Treatments

An innovative channel design was employed for the Balarat Gulch diversion channel. The design imitated natural channel form and function, incorporated naturalizing elements, and created aquatic and riparian habitat.

A step-pool configuration was built into the channel since this channel form is typical of high-gradient alpine streams. These systems use frequent drops to dissipate energy, as opposed to flatter gradient, valley floor systems that dissipate energy by meandering. The ranges for height and spacing of drop structures, which were used to create the step-drops, were determined based on observations and measurements of the step-drops in the reaches above and below the diversion channel. The closely spaced step-drops achieve flatter between-drop slopes and they create natural flow variability with areas of faster and slower moving water.

While the channel was designed to withstand flows in excess of the 100-year storm, a mobile bed utilizing soil and rock gradations found in the natural channel was specified as a surface treatment. The surface material is mobilized frequently by lower intensity, higher recurrence interval storms. This mobility allows natural scour and deposition cycles to occur,

which can form localized pools and develop a low flow channel. The creation of deeper water prevents overly wide, shallow flow, which is a common constraint to aquatic habitat. The mobile bed treatment was underlain by a resistive grouted riprap layer to provide vertical protection against lowering of the channel invert. Channel lowering could not be allowed due to the mine workings below.

The development of a low flow channel was further encouraged by creating small notches in the tops of the drop structures. Notches were designed to follow a random, alternating pattern down the channel to promote low flow sinuosity.

Natural materials were given preference during design of bed and bank treatments. Concrete or grouted riprap were avoided as surface layers, favoring natural rock and boulders to provide the required surface protection.

The comprehensive revegetation plan, utilizing all native species, benefited the newly created channel by restoring riparian vegetation wherever possible. Native riparian trees were specified along the lower reach of channel, where impermeable lining or exposed bedrock did not preclude their use. Restoring the riparian zone along the channel provides shading and cooling of streamflows, protective overhead cover, and terrestrial habitat. Streamside vegetation also helps to stabilize banks and functions as a detritus source for the aquatic system, forming the base of the aquatic food chain.

Waterfowl Protection

An old mine tunnel at the south end of the site has become permanently flooded and causes a constant discharge from the overlying pond. The flooded area is known as the "mine pond". Water in the pond has a low pH and heavy iron staining exists along the discharge path from the pond.

While the pond and its discharge had to be excluded from this VCUP project due to point source discharge issues, concerns for the health of waterfowl that would be tempted to land in the pond were addressed. Bird BallsTM, which were recommended by the U.S. Fish and Wildlife Service, were used to cover the pond surface, preventing waterfowl from landing or residing in the pond, and removing potential contamination pathways. Photograph 3 shows the Bird BallsTM covering the mine pond.

Native Revegetation

The sitewide revegetation plan for the mine site used only native species

and included a diverse mix of herbaceous and woody species. Plants were specified to accommodate the low moisture environment and the heterogeneous nature of the site, including pockets of low nutrient and potentially low pH conditions.

Photo 3: Bird Ball^{TM} installation to protect waterfowl

Riparian tree and shrub species were installed along appropriate reaches of the diversion channel, as well as located below the diversion channel to supplement existing vegetation. Riparian species included mountain willow, Rocky Mountain maple, thinleaf alder, river birch, twinberry, chokecherry, and golden currant. Additional upland plantings included ponderosa pines specified for installation along Balarat Hill Road to help screen the site and for improved site aesthetics.

Two seed mixes were specified for the site. A "waste rock seed mix", used at the waste rock repository, specified species able to germinate and establish under low pH, low moisture, and low fertility conditions. A "site seed mix" was applied throughout the rest of the site and included a wider variety of herbaceous species and provided numerous wildflower species for improved site aesthetics.

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