CHARACTERIZATION AND DESIGN OF THE OLD DOMINION REMEDIAL ACTION PLAN[1]

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Abstract: The Old Dominion Mine in Arizona's Globe-Miami mining district includes three tailings piles, one slag pile, and numerous waste rock dumps. The mine waste materials were generated from different operations between 1881 and 1931. The Old Dominion Remedial Action Plan (RAP) is an innovative program developed for remediating the impacts of historic mining activities on portions of the Old Dominion property in the Upper Pinal Creek drainage. Agency oversight is jointly provided by the U.S. Environmental Protection Agency and the Arizona Department of Environmental Quality. The goal of the remediation is to stabilize the mine waste materials, mitigating impact to groundwater and surface water to the maximum extent possible. The RAP was recently approved by the agencies and provides for physical and chemical stability of the mine waste materials. Considerations in the design included the high acid generating nature of the tailings and waste rock and the existing erosional and structural instability of the piles. Further, the site is subject to high intensity flows from stormwater runoff during the summer monsoon season and is located adjacent to an active railroad and a well-traveled state highway. Site characterization has included extensive static testing to determine the acid generating potential of the tailings and waste rock and detailed stability modeling. As a result, remedial measures include a 75-cm thick evapotranspirative soil cover and a 100,000 m^3 rock buttress for stabilization of critical tailings slopes. Additional components of the RAP design include concrete cutoff walls and a complex network of lined diversion channels. This paper describes the results of the 8-year design and approval process.

Additional Key Words: Reclamation, Tailings, Source Control, Mine Site Closure, Site Characterization.

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History of the Old Dominion Mine

Copper mining began in the Globe district of central Arizona in 1878. The Old Dominion Mine (see Figure 1 for location) extracted its first copper in 1881 with significant copper production commencing in 1882. By 1888, the mine was producing nearly 3 million

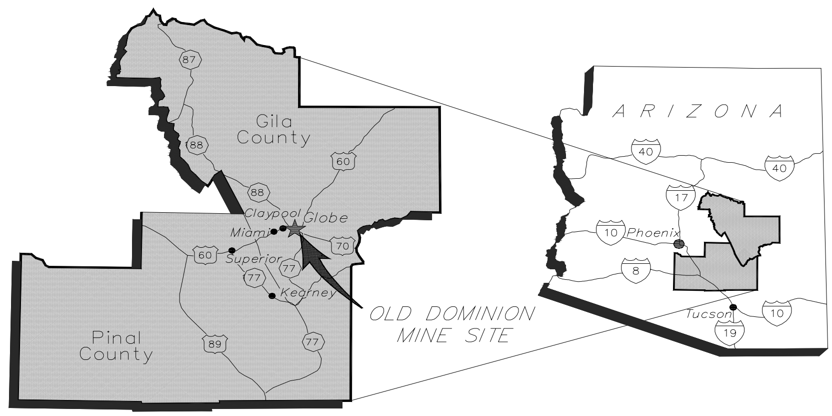

Figure 1. General Location Map

kilograms (kg) of copper a year. By 1896, the mine was expanded and produced an average of 12 million kg of copper a year.

The Old Dominion Mine originally started under the name Old Dominion Copper Company and later the Old Dominion Copper Mining & Smelting Company. At this time, Phelps Dodge & Company operated the neighboring Buffalo and United Globe mines. In 1904, the Old Dominion Copper Mining & Smelting Company merged with United Globe Mines to form the Old Dominion Company. The Old Dominion Company then operated both area mines under the control of Phelps Dodge & Company.

The ore body at the Old Dominion was emplaced within a northeast-southwest trending fault zone. Mineralization generally occurs as open space filling in large fault zone breccias and in typical vein assemblages. The causative hydrothermal activity is associated with Laramide-age multi-phase granitic intrusions from nearby copper porphyry deposits. Common host rocks range from Precambrian mafic intrusives to Paleozoic metasediments.

During the early years (1892) the upper levels of the mine revealed copper oxide mineralization with grades up to 12%. However, toward the end of the mine's life (1930) the lower levels revealed lower grade (2%) primary sulfide mineralization.

The mine itself finished at 700 meters (m) deep on 27 levels. The main shaft, A-Shaft, was rebuilt in 1929 and included a 5-compartment raise. In its heyday, the Old Dominion smelter had a capacity of 1,000 tons per day and the concentrator had a capacity of 1,400 tons per day. Up to 1,500 people had been employed at the Old Dominion Mine at its peak.

During its half-century of operation, the mine produced about 347 million kg of copper, 89 thousand ounces of gold and more than 4.5 million ounces of silver. These resources had a total value of $125 million (1930 dollars).

Introduction

In December 1994, Magma Copper Company signed a consent decree (USDC, 1994) with the U.S. Environmental Protection Agency and the Arizona Department of Environmental Quality (ADEQ) for alleged violations of the Clean Water Act and associated permits at Magma's Pinto Valley Operations. BHP Copper, as the successor to Magma, is obligated under this consent decree to perform a Supplemental Environmental Project (SEP) at the inactive Old Dominion Mine (see Figure 2). The remedial action is required to mitigate, to the maximum extent practicable, the contribution of contaminants from the Old Dominion Mine into the Pinal Creek drainage.

Prior to the SEP's effects at the Old Dominion Mine, the Pinal Creek drainage was designated a Water Quality Assurance Revolving Fund (WQARF) site by ADEQ in 1989 due to acidity and metals contamination in the alluvial aquifer. The WQARF program is the state equivalent of the Federal "superfund" program. The remedial action required in the 1994 Consent Decree is a source control activity under the WQARF program and such actions are referenced in the WQARF Consent Decree signed in 1997 (USDC, 1997).

Figure 2. Oblique Aerial Photograph of the Old Dominion Site

As required by the 1994 Consent Decree, an investigation and feasibility study or Recommended Remedial Action Plan (RRAP) was completed (Hargis & Assoc., 1996). The RRAP included conceptual options for remediating the site. The RRAP investigation showed that stormwater runoff from the site affects surface water downstream. Although groundwater in the immediate vicinity is not affected, apart from impacted surface water that migrates directly into shallow groundwater of Upper Pinal Creek, the impacted stormwater and associated sediment eventually make their way downstream into Lower Pinal Creek where they have the potential to contribute to groundwater quality impacts.

Source control engineering has been performed to meet both the requirements of the 1994 Consent Decree and the WQARF source control program as well as all other applicable programs including the Comprehensive Environmental Response Compensation and Liability Act, the National Contingency Plan, the U.S. Army Corps of Engineers 404 Permit Program, and the National Pollution Discharge Elimination System Program. Source control engineering has addressed the tailings, waste rock, and slag piles (see Figure 3) to mitigate potential sources of impacted stormwater from the Old Dominion Site.

The Old Dominion RRAP, a 94-page document, provided the general physical and chemical characteristics of the mine waste materials and provided an outline for remediating the impacts of historic mining activities at the Old Dominion Site. The RRAP found that the potential contaminants associated with the source areas (tailings, waste rock, and slag) consisted of acidic solutions generated by the oxidation of sulfide minerals, metals, and sediment loading from erosion of the areas by stormwater runoff. In addition, stormwater runoff from the mine site was found to be acidic. Hence, the RRAP recommended that recontouring, capping, and stormwater controls be designed to control erosion and sedimentation from the source areas.

Specifically, the source control methods described in the RRAP included implementation of the following remedial measures:

- Regrading of tailings piles and waste rock dumps;
- Construction of diversion channels to intercept run-on from upgradient watersheds and to collect runoff from reclaimed surfaces;
- Placement of a soil cover to enhance vegetation; and,
- Implementation of revegetation on the regraded tailings and waste rock surfaces.

Topographic Setting and Drainage Patterns

The Old Dominion Site is located approximately 130 kilometers (km) due east of Phoenix, Arizona. The mine facilities are located adjacent to the city of Globe in Gila County and are clearly visible from Highway 60. The Arizona Eastern Railroad runs parallel to the western property boundary at the toe of the slag and tailings piles.

The terrain around the Old Dominion Mine is somewhat rugged (see Figure 2). This area of Gila County is comprised of rolling hills and mountains up to 2,400 m high. At these elevations, there is a wide variety of annual climatic changes, ranging from -10°C and snow in the winter months to temperatures exceeding 40°C and intense monsoonal rainstorms in the summer months. Surface runoff leaves the surrounding mountains east of the site primarily in Big Johnnie, Buffalo, Alice, and Copper Gulches and enters Upper Pinal Creek around and through the Old Dominion Site. Portions of the Pinal Mountains to the west also drain into Upper Pinal Creek south and west of the site. Underground water remains confined to the 12th Level (approximately 300 m deep) and below. Water from the underground workings is pumped for operational uses at area mines but is never in contact with the disturbed areas on the surface.

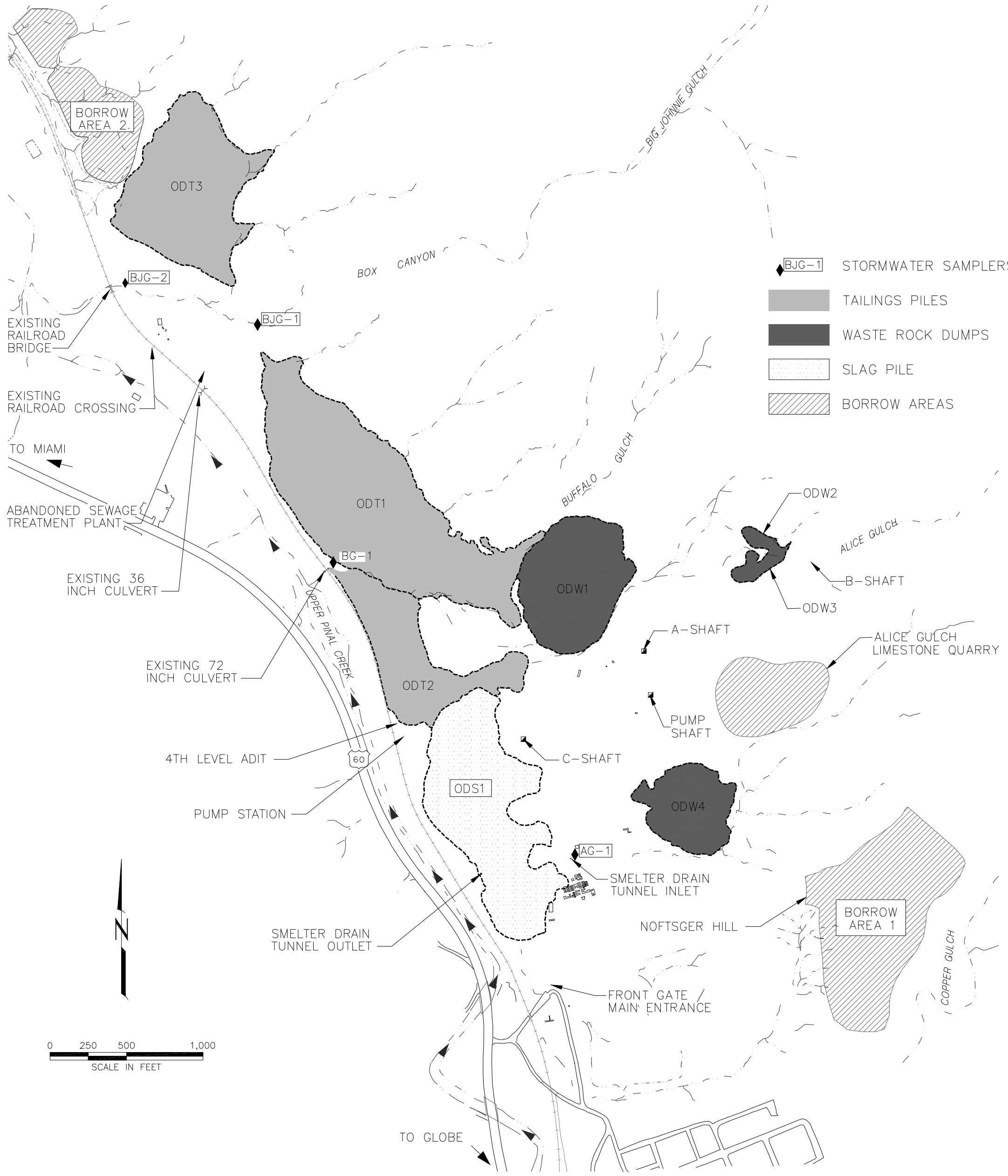

Figure 3. Old Dominion Site Map.

Site Characterization

Preliminary site characterization was provided in the RRAP. The RRAP followed the general sampling and testing requirements provided in the 1994 Consent Decree. Rather than include engineering designs, the RRAP included general concepts for the remedial plan, such as general slope angles and diversion channel alignments. The RRAP evaluated several remedial alternatives for the mine wastes including no action, reprocessing, runon/runoff controls, recontouring, capping, revegetation, slurry pumpback, and various other specialty options. As mentioned previously, the RRAP recommended a preferred alternative for remediation that included runon/runoff controls, recontouring, capping, and revegetation. Following EPA approval of the RRAP in 1997, further characterization was then required to develop the final design of the preferred alternative.

Tailings Piles

Three tailings piles referred to as ODT1, ODT2, and ODT3 total approximately 60 acres. Side slopes are up to 30 m high and vary from as steep as 1.4 horizontal (H): 1 vertical (V) to 3H:1V. Visual observation of the tailings impoundments indicate that excessive erosion has occurred down the impoundment slopes.

The tailings generally consist of fine to medium sands with interbedded slimes layers. The tailings overlie native alluvial deposits and the Apache Leap Dacite. The sands are non-plastic silty sands (USCS classification) with an average moisture content of 10%. Slime layers as thick as 4.5 m are low to medium plastic clayey silts and silty clays with moisture contents close to or at their liquid limit. Field and laboratory testing performed on the slimes indicate undrained shear strengths as low as 29 kPa and a coefficient of consolidation equal to approximately 11 cm^2/day.

The tailings piles are comprised of mostly copper sulfate as a byproduct of acid rock drainage (ARD). When stormwater contacts the tailings, ARD is generated by the weathering of primary sulfides causing the disassociation of iron and sulfate thereby creating sulfuric acid and ionic species of metals in solution. The low pH environment created by ARD allows for greater dissolved concentrations of metals within stormwater runoff including copper, iron, arsenic, lead and zinc. Low pH values occur within an oxidation zone that extends approximately 3.5 m from the pile surface.

Waste Rock Piles

Four waste rock dumps lie east of the tailings piles totaling approximately 10 hectares. The dumps are up to 60 m high with existing slopes from 1.5H:1V to 1.6H:1V. Similar to the tailings piles, excessive erosion has occurred down the dump faces where the rock grain size has been measured to be as fine as silty sands. The waste rock typically consists of low plasticity silts and silty sands with gravel and boulder-sized material in select locations. Based on site specific testing, the waste rock dumps have the potential to generate acid and produce low pH values throughout their depths.

Two types of waste rock dumps exist due to the two types of mineralization that occurs at the Old Dominion Site. Fault-controlled cordilleran vein deposits with specularite, chrysocolla and copper carbonates occur where intermediate to mafic igneous bodies have intruded Paleozoic limestones and dolomites. Porphyry related oxide and sulfide mineralization occurs where felsic to intermediate igneous bodies have intruded sedimentary and igneous mafic host rocks. The sulfide bearing waste rock has a high tendency to generate acid when stormwater runon infiltrates and begins the weathering process of the sulfides. Stormwater runoff from the larger waste rock dumps have very low pH values as well as high dissolved concentrations of ionic metal species that include copper, lead, arsenic and zinc as well as high sulfate concentrations.

Waste rock dumps that were created from the mining of the specularite assemblage exhibit a much lesser tendency to generate acid than the sulfide bearing waste rock dumps. The 4 large waste rock dumps within the SEP area are separated by material type due to fault-controlled mineralization. The southeastern flank of the SEP area contains the non-acid generating waste rock dumps. The northwestern flank contains the acid generating waste rock dumps. The two flanks are separated by a large mineralized fault zone.

<u>Slag Pile</u>

Slag from the old copper smelter lies south of the tailings piles; the aerial extent of the slag dump (ODS1) is approximately 8 hectares. The dump faces are up to 25 m high with slopes ranging from near vertical to 1.5H:1V.

The slag material has a specific gravity of 3.5 and contains quantities of arsenic in exceedance of ADEQ Soil Remediation Levels (SRLs). However, leachability tests have indicated that the slag has essentially no potential to leach.

Surface Water

The Old Dominion Site is located along the east bank of Upper Pinal Creek. Upper Pinal Creek in this area is ephemeral, flowing southeast to northwest in response to direct precipitation, stormwater runoff, or snow melt. Numerous historic mine sites are located in the upgradient hills of the site. The topography of this area slopes from northeast to southwest. Runoff from these areas is conveyed through several tributaries (Copper, Alice, Buffalo and Big Johnnie Gulches) prior to contributing to Upper Pinal Creek. Surface water flow is present in these tributaries during periods of significant precipitation only. The first flush of storm runoff from the tailings and, to a lesser extent, the waste rock, is highly acidic and contains elevated metal concentrations.

Four stormwater samplers were installed in three select drainages where stormwater runoff flows at the Old Dominion Site. Three of the four samplers have been placed such that they collect runoff after it has contacted either tailings piles or waste rock dumps (see Figure 4). The fourth sampler was placed upstream from any tailings or waste rock dumps.

Sampler BG-1 has been in place since the second quarter of 1999. Due to its early placement, there is sufficient data to begin to analyze possible trends in the geochemistry. Samplers BJG-1, BJG-2 and AG-1 were installed during the fourth quarter of 2001 and have little data.

BG-1 is in Buffalo Gulch at the toe of ODT2. Storm flow collected at BG-1 comes from two distinct drainages. The first is surface water runoff flowing in No Name Gulch, which flows around the west side of ODW1. The second is surface water flow from portions of the Old Dominion Plant Site. Both sources run onto ODT2 then flow down to BG-1.

There are eleven samples to date that have been collected at BG-1. Values of pH are consistently between 2 and 3; metal species whose concentrations are consistently elevated include arsenic, copper, manganese, zinc, cadmium, chlorine, fluorine, nickel and selenium.

Figure 4. Sample point BG-1 in drainage to left of sampler (right-center) at toe of ODT2.

Groundwater

The Old Dominion Site is considered a hydrologic sink due to the historical pumping of large amounts of water. Substantial inflows into the mine still occur due to pumping of mine water for industrial purposes.

The majority of the local aquifer is contained within the quaternary Gila conglomerate. Alluvial deposits within the reaches of Upper Pinal Creek and its tributaries are comprised mostly of reworked detritus from the Gila conglomerate.

The groundwater system exists in two hydrogeologic units around the Old Dominion Site. The uppermost unit is the surficial flow within the alluvium and the uppermost weathered layers of the underlying bedrock. The bottom unit is a deeply circulating, discontinuous system that includes bedrock and indurated sediments of the Gila conglomerate.

Design Challenges

The closure objective for the Old Dominion Site is to minimize, to the maximum extent practicable, the potential for release of acidity and metals to surface and/or ground water.

The potential pathways for migration of acidity and metals from the Old Dominion Site are by:

- Surface water erosion of acid generating materials;
- Surface water contact with acid generating materials; and,
- Infiltration of precipitation into acid generating materials.

Measures for controlling surface water erosion and surface water contact include stabilizing the surface of the waste and providing an erosion resistant cover. Measures to control infiltration and surface water contact include surface grading and placement of a cover to reduce infiltration.

Remediation Concepts

The intent of the remediation effort was to provide a final condition for the tailings and waste rock 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. Per the approved RRAP, the stabilization of the tailings and waste rock will include regrading of the piles, construction of runon and runoff diversion channels, armoring of the side slopes, and incorporation of amendments into the surface cover of the regraded tailings to facilitate revegetation of the cover soil (Montgomery Watson, 1999).

Stability Concerns

A review of available geotechnical data and a stability analysis was completed for each tailings pile. Stability concerns at one of the tailings piles, ODT1, was 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 at ODT1 is presented below.

At ODT1, several layers of slimes had been identified, during the auger drilling program, that potentially extend near the 3H:1V cut slope. The split spoon sampler had, at times, pushed through these slimes layers under its weight alone. And in some cases the *in-situ* moisture content of the slimes were at or very close to their Liquid Limit.

ODT1 could be considered an upstream constructed impoundment where the tailings were spigoted from the perimeter of the impoundment with the sand fraction generally settling out near the perimeter and the finer slimes generally settling at the interior of the impoundment. A rake-type classifier separated the sand and slime at the discharge point on the embankment. The sand was then deposited to form a dam 518 m long. The classifier was shifted ahead on tracks as the dam was built up. The tailings were reportedly 50 to 55 percent minus 200 mesh. It was 20 to 25 percent pyrite and over 5 percent hematite (E&MJ-Press, 1925).

ODT1 is located adjacent to the railroad and Upper Pinal Creek 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.

Seepage through the tailings was not a concern since no visible seeps could be seen around the tailings pile and two standpipe piezometers installed in 1997 have remained dry to this day.

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.

Following a review of the geotechnical stability of the pile, it was apparent that a 3H:1V cut slope would intercept the slimes layers thereby compromising its structural integrity. Slope stability design criteria was based on a static factor of safety of 1.3 and pseudostatic factor of safety of 1.1, per EPA requirements. A horizontal ground acceleration of 0.11g (1,000-year return period) was used in the pseudostatic analysis. The material parameters used in the slope stability analysis were determined from laboratory analysis of select field samples and from drilling conditions and are provided below in Table 1.

Table 1. Material Parameters Used in Stability Analysis

Material Type	Moist Density (kg/m^3)	Sat. Density (kg/m^3)	Cohesion (kg/m^3)	Friction Angle (°)
Tailing Sands	1601	1762	0	32
Tailing Slimes	1441	1601	9611	0
	1601	1762	4805	25
Waste Rock	1762	1633	0	32
Rock Buttress	1922	2162	0	42
Bedrock/Native	2242	2402	19,222	40

Infiltration Concerns

Due to the high acid generation potential of the Old Dominion tailings and waste rock, infiltration control was required to minimize surface water contact with the materials. As required by the 1994 Consent Decree, the EPA's Hydrologic Evaluation of Landfill Performance (HELP) model (Schroeder et al, 1994) was first used to analyze the infiltration potential of various cover section alternatives. However, as it has been documented in numerous cases of infiltration cover design, the HELP model is commonly used to evaluate cover alternatives only and not specifically for final design. Therefore, the SoilCover model, developed by the University of Saskatchewan (2000), is better suited than HELP for modeling covers in arid areas, where the annual potential evapotranspiration greatly exceeds the annual precipitation. SoilCover accounts for upward flow of water within the soil section resulting from drying at the soil surface. In addition, SoilCover more accurately handles the surface infiltration at the soil surface. SoilCover is a one-dimensional model that calculates runoff based on the infiltration potential of the surface of the soil. In other words, if the surface of the soil is saturated and the application rate for the precipitation is greater than the saturated hydraulic conductivity, the excess application rate is accounted for as runoff. In a similar manner, if the soil is unsaturated, the unsaturated hydraulic conductivity (less than the saturated hydraulic conductivity) is used to calculate the infiltration as the soil moves towards saturation.

SoilCover infiltration analyses were therefore completed for the existing tailing condition, two feet of cover soil over the tailings and three feet of cover soil over the tailings. The infiltration analysis evaluated the effectiveness of the cover for limiting infiltration to the tailings for an average year and the wettest year based on the twenty years of mine records available for the Miami Unit weather station. The average year used in the analysis was from the calendar year 1994 with a total annual precipitation of 53 cm and the wet year used was 1978 with a total annual precipitation of 92.4 cm.

Results for the SoilCover analysis are summarized in Table 2 for the average annual precipitation and in Table 3 for the wet year. The data presented in the tables is a percentage of the annual precipitation that is accounted for as evapotranspiration (ET), runoff and the amount passing through the cover section and actually contacting the tailings. The term "% Stored in Soil" represents the amount of water that is stored, or removed, from the cover soil during the year. This term represents the storage portion of the water balance, with other terms representing inflow and outflow of water.

In modeling the existing conditions it was assumed that water passing downward through the model node at a 1 m depth was the "deep percolation" contacting the tailings at depth. The conclusion that can be drawn from the results of the existing condition modeling is that net water

(-4.2% stored in soil) is actually removed from the top of the tailings profile by the end of the year. Additionally, during the average year very little of the water contacting the tailings actually goes deeper in the tailing profile (0.1%). Practical observation bears this out since the tailings were placed in a saturated condition and are drying out to depth over time as noted in the field investigation.

Table 2. Average Year Fate Water as a Percentage of Total Annual Precipitation

Cover Section	% ET	% Runoff	% Stored In Soil	% Infiltrating
Existing	39.5%	64.6%	-4.2%	0.1%
60 cm Soil	66.2%	33.3%	-0.4%	0.1%
90 cm Soil	67.2%	33.7%	-0.8%	0.1%

Table 3. Wet year Fate Water as a Percentage of Total Annual Precipitation

Cover Section	% ET	% Runoff	% Stored In Soil	% Infiltrating
60 cm Soil	48.3%	50.3%	0.3%	1.1%
90 cm Soil	47.7%	47.4%	3.5%	1.4%

Stormwater Control Concerns

Hydrologic analyses completed for the site included determining the quantities and peak rates of runon and runoff that need to be conveyed away from the SEP facilities, and evaluating of the peak flow rate in Upper Pinal Creek to determine the potential impact of creek flows on the SEP facilities. The hydrologic calculations were performed utilizing the HEC-1 and HEC-2 computer programs developed by the U.S. Army Corps of Engineers (1991 and 1990). The 100-year 24-hour, 6-hour, 2-hour, and 1-hour storm events were used for the runon calculations. A 100-year 24-hour storm event was used for the evaluation of the Upper Pinal Creek floodplain adjacent to the site.

Referring to the NOAA Atlas map for Arizona, the Old Dominion Site experiences 11.7 cm of rainfall from the 100-year 24-hour storm event. Local studies of more recent rainfall data suggest that the isopluvials developed for Globe, Arizona and surrounding areas are conservative approximations. A correlation between NOAA Atlas values and actual data was used to more accurately estimate the design storm event. This adjustment is currently used at other mining properties in the Globe-Miami area and is based on 75 years of recorded data at the Miami Unit weather station located approximately 8 km north of the site. Applying the adjustment results in a design precipitation of 9.4 cm for the site.

The stormwater control plan has been developed to mitigate erosion and infiltration by controlling surface water runon to and runoff from the mine waste piles. Proposed structures to control surface water around the perimeters of the piles include diversion channels and energy dissipation structures at appropriate discharge points and on steep slopes. The drainage control alternatives have been designed to ensure compliance with regulatory requirements and sound engineering practice.

The three tailings piles will each have diversion channels constructed along their interior (eastern) edges. The channels will collect flow from the reclaimed tailings surfaces and intercept stormwater runon from the watershed areas above the piles. Diversion channels will also be constructed at the upstream edges of the waste rock dumps.

The peak discharges for the 100-year 24-hour storm event for the proposed diversion ditches are included in Table 4, some of which are shown on Figure 5.

Similar to the calculation of a design precipitation for the Old Dominion drainage basin, an adjustment was applied to rainfall data for the Upper Pinal Creek drainage basin to more accurately estimate the design storm event. The design storm event for the Upper Pinal Creek drainage basin was determined to be 10.4 cm.

Table 4. Calculated Flow Rates for Proposed Diversion Ditches

Channel I.D.	Peak Discharge (m^3/s)
ODT3-E	5.13
ODT1-E	10.39
ODW1-S	5.66
ODT2-E	2.21
ODS1-E	0.65
ODW4-N	0.45
ODW4-S	11.01

ODW2-N	0.40
ODW3-S	0.08
Existing Railroad Culvert	17.20

Results of the HEC-1 analysis have been used to determine if the peak flow in Upper Pinal Creek has the potential to contact any of the SEP facilities (specifically, ODT1 and ODT2). Using a watershed drainage area of approximately 56 km, the peak discharge from the 100-year 24-hour storm event was calculated to be approximately 260 m^3/s. HEC-2 modeling of Upper Pinal Creek was then completed to determine the extent of the flood plain where it flows immediately adjacent to the tailing piles. The results of this analysis have shown that there would be no contact of surface water flows in Upper Pinal Creek with the tailing material, with the exception of where flows potentially back up the Buffalo Gluch culvert under the railroad tracks. At every other location where Upper Pinal Creek runs adjacent to the mine site, the railroad embankment serves to protect the tailing piles from the design storm event. Upper Pinal Creek would not overtop this embankment and therefore, does not encroach upon the tailing.

Remedial Design

Regrading

Side slopes of the facilities will be regraded to an approximately 3H:1V slope where practicable. The exception is approximately 25% of the side slopes of ODT1, which will be regraded to 2.5H or 3H:1V or buttressed to 2H:1V. Where the footprint of ODT1 can be increased, waste rock from ODW1 may be used to buttress and also to flatten the existing slopes to 3H:1V. Where the toe of the pile is restricted by the proximity of the railroad, slopes flatter than 2.5H:1V might expose weak slimes layers resulting in a final configuration that is not as stable as a 2.5H:1V final slope. Therefore, the existing slopes in this location will be regraded to 2.5H:1V and buttressed using rock from a local borrow source. Top surfaces will be regraded to slope away from the pile crests at a grade of approximately 4%. Over 600,000 m^3 of mine waste material will be moved in the regrading. Figure 5 provides a general schematic of the remedial measures designed at ODT1, ODT2, and ODW1.

Vegetative Cover

The top surfaces will be covered with an average 75 cm of natural soil. The amount of oversized rock will be minimized in the soil layer to enhance plant growth. Specifically, 75 percent or better is required to pass the 5-cm mesh. Plant species appropriate to the area will be seeded on the reclaimed surfaces.

To minimize over compaction during the placement of the cover material, no vibratory compaction devices will be used. The natural compaction achieve by the equipment driving over the surface while spreading the cover material is expected to provide adequate compaction. Infiltration of precipitation and surface water into (and hence contact with) the mine waste is expected to be negligible for the remedial cover design since the top surfaces will be sloped at approximately 4 percent which will increase stormwater runoff. In total, over 345,000 m^3 of cover soil will be used in the vegetative cover layer.

The slag pile will not be covered since it has been determined that it does not have the potential to leach metals or generate acid. However, a ditch will be constructed to divert stormwater runoff around the pile. Additionally, the slag surface will be rough graded or plugged in areas where large voids or openings have developed to ensure the safety of the public.

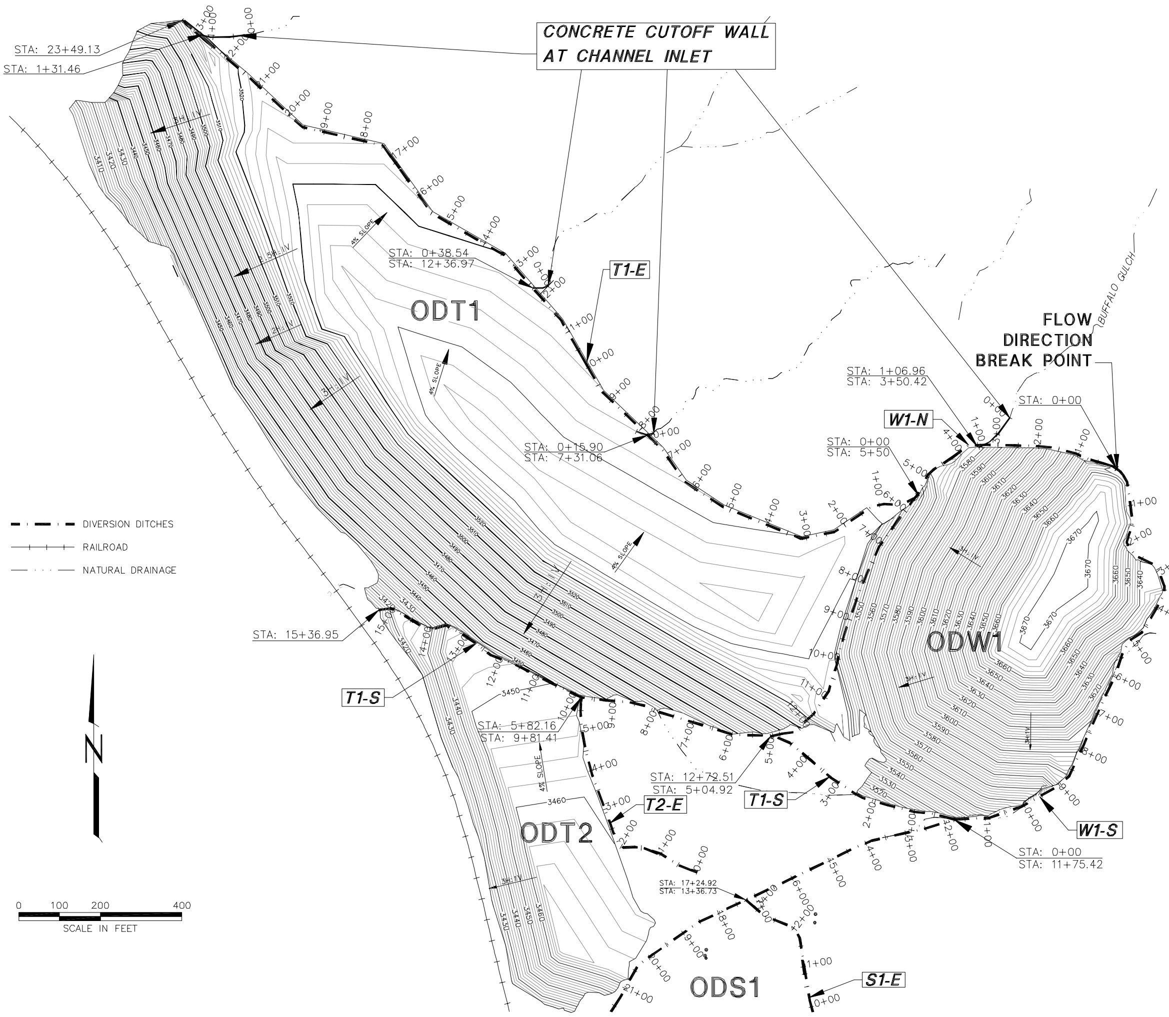

Figure 5. Tailings/Waste Rock Source Control Measures.

Erosion Cover

All side slopes will be covered with an average of 60 cm of soil and 15 cm of rock resulting in a total cover thickness of approximately 75 cm of natural material. The 15 cm thick rock veneer layer is sized to remain erosionally stable based on the peak flow generated by the 100-year, 24-hour storm or 100-year, 1-hour storm event, whichever is larger. Rock veneer sizes are dependent upon the runoff flow distance down the slope and typically average 3.8 cm or 8.6 cm in diameter.

Revegetation

In general, revegetation will start at the upwind border of each disturbance and proceed downwind. Operations will be conducted along contours to avoid creating conditions that promote downslope water flow patterns. The cover material will be roughened before fertilizer application to eliminate surface crusting and to prepare the seedbed for seeding. A nominal application rate for fertilizer of 18 kg N, 27 kg P_2O_5, and 27 kg K_2O will be required per acre of placed cover. The broadcast method is preferred for seeding and will take place immediately following the completion of seedbed preparation. Due to the variety of seed types, frequent mixing within the hopper will be required to prevent differential seed settling which results in an uneven planting distribution of species. Given the high evapotranspiration rates of the region, mulching will also be required for disturbed area outslopes on the tailings piles and waste rock dumps, particularly on the south and west facing slopes where incident sunlight is greatest. The use of irrigation will not be encouraged and may only be used to ensure the establishment of the species by supplementing natural precipitation rates in years of below average precipitation.

Agronomic soil analyses will be conducted during construction to determine accurate amendment quantities. The final seed mix will be developed using a native species list and applied at an appropriate rate to achieve a vegetation cover similar to the surrounding areas.

Stormwater Controls

The diversion channels have been designed to intercept runon from the watershed areas above the site and also collect runoff from the reclaimed surfaces. In general, the diversion channels will be trapezoidal and lined with 10 cm thick fiber-reinforced shotcrete or riprap (up to 76 cm average size) for erosion resistance. Riprap (30 cm average size) will be used at drainage interceptor points and on steep channel grades to dissipate energy. Similar to the existing natural drainage pattern at the site, the proposed diversion channels will eventually discharge into Upper Pinal Creek. The channel dimensions have been sized to accommodate the larger peak discharge from either the 100-year, 1-hour or 100-year, 24-hour storm event.

As a result of final engineering design, the following additional source control methods were therefore added to those described in the RRAP:

- Removal and consolidation of miscellaneous (scattered) tailings and waste rock;

- Regrading of several additional tailings and waste rock areas;
- Construction of culverts and energy dissipation structures;
- Placement of a rock slope cover to control erosion;
- Placement of riprap and rock armoring for flood protection;
- Construction of a rock buttress to improve stability; and,
- Demolition of some of the unsafe buildings and foundations in the old plant site.

Other issues to be considered during construction

Ecological considerations

A comprehensive field investigation was executed that provided evidence of bat use by two colonies of bats in some of the abandoned mine structures. One colony was found in the sampling mill tanks and in the tunnels under the concentrator. Another colony was observed in the access under the concentrate bins. These three structures will likely receive protection from disturbing visitation and/or vandalism in the form of bat compatible gates installed at the access points.

Preservation and protection of former mine structures

More than 50 independent former mine structures are still present at the Old Dominion Site. For safety reasons, approximately 14 of the structures will require demolition. In addition, a total of 26 asbestos containing building materials (ACBMs) have been identified that will be removed and disposed of by a certified asbestos abatement contractor during implementation.

Adjacent and nearby properties

The active Arizona Eastern Railroad runs along the western property boundary. Considerations during construction activities are required for potential service interruptions, railroad crossings, safety issues, and protection of the railroad track.

In addition to the railroad, there are several residential and municipal properties, currently in use, located in close proximity to the site. A plot of land adjacent to ODT1 near ODW1 is privately owned and is only accessible through BHP property. The City of Globe Sewage Treatment Plant is located adjacent to the railroad and BHP property.

Access considerations

Existing institutional controls to restrict public access to the site include fencing and posting. Further access controls are currently being considered for the period following remediation of the site.

Preservation and protection of utilities

Several pipelines are currently in use at the site. These include the industrial water pipelines and potable water pipelines. In addition, power and miscellaneous site utilities cross the site. In general, pipelines will be secured and protected both during and after construction to ensure that they do not create unacceptable risks to environmental values. Pipelines will generally be left in place to minimize surface disturbance. However, access will be provided to these utilities for maintenance reasons.

Reporting

A Remedial Construction Plan (RCP) was approved by EPA and ADEQ in July 2002. Based on the technical specifications included in the RCP, 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 will be made.

Monitoring/Permitting

An integral part of the SEP is baseline water quality data. The stormwater samplers in place on site that collect stormwater runoff from disturbed materials are the source of that baseline data. This baseline surface water quality monitoring will take place leading up to and during construction. As part of the 1994 Consent Decree, there will also be 4 quarters of post-construction surface water quality monitoring against which the baseline data will be compared to demonstrate the improvement of water quality directly related to SEP remediation.

A Construction Storm Water Pollution Prevention Plan (SWPPP) was required and has been developed for the SEP remedial construction. As part of the compliance with the construction SWPPP program, 14-day inspections as well as daily visual inspections will be performed for all erosion and sediment control Best Management Practices (BMPs). This plan will also include spill prevention and response procedures related to the construction project.

A U.S. Army Corp of Engineers 404 Permit will also be obtained, as there are three potentially jurisdictional waterways within the Old Dominion Site. This permit will allow construction to take place within those waterways.

Dust control is also a concern with heavy construction equipment working on tailings and waste rock in an arid environment. A dust control-monitoring program will be developed. There will be 4 monitors placed around critical points along the perimeter where fugitive dust may migrate. Permissible Exposure Limits (PELs) will be developed for this project based on the local soil geochemistry. Geochemical data will be used to calculate possible concentrations of metals of concern within dust created on the tailings and waste rock piles. Using the calculated values, an overall dust concentration limit will be set so as not to exceed PELs for any metals of concern. Water trucks will be the main source of dust mitigation throughout the construction project.

Conclusions

All remedial activities specified for the Old Dominion SEP are based on classic source control theory. The site is now in the construction phase. Immediately following completion of construction, BHP will commence four consecutive quarters of stormwater sampling to check its compliance with the requirements of the 1994 Consent Decree.

The challenges during design of the Old Dominion remediation included access limitations caused by the proximity of the active railroad and Upper Pinal Creek, high volumes of runoff during summer monsoons, numerous former mining structures, and a high profile site adjacent to a busy state highway and city residences. These limitations required careful planning in order to benefit the most from the complex site conditions.

The successful design and approval of the Old Dominion RAP has become a model environmental remediation project for the desert southwest, completed in close cooperation with federal and state agencies and local citizen groups.

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