# The Hermosa Mine Proposal

## Potential Impacts to Patagonia's Water Supply

Patagonia Area
Resource Alliance

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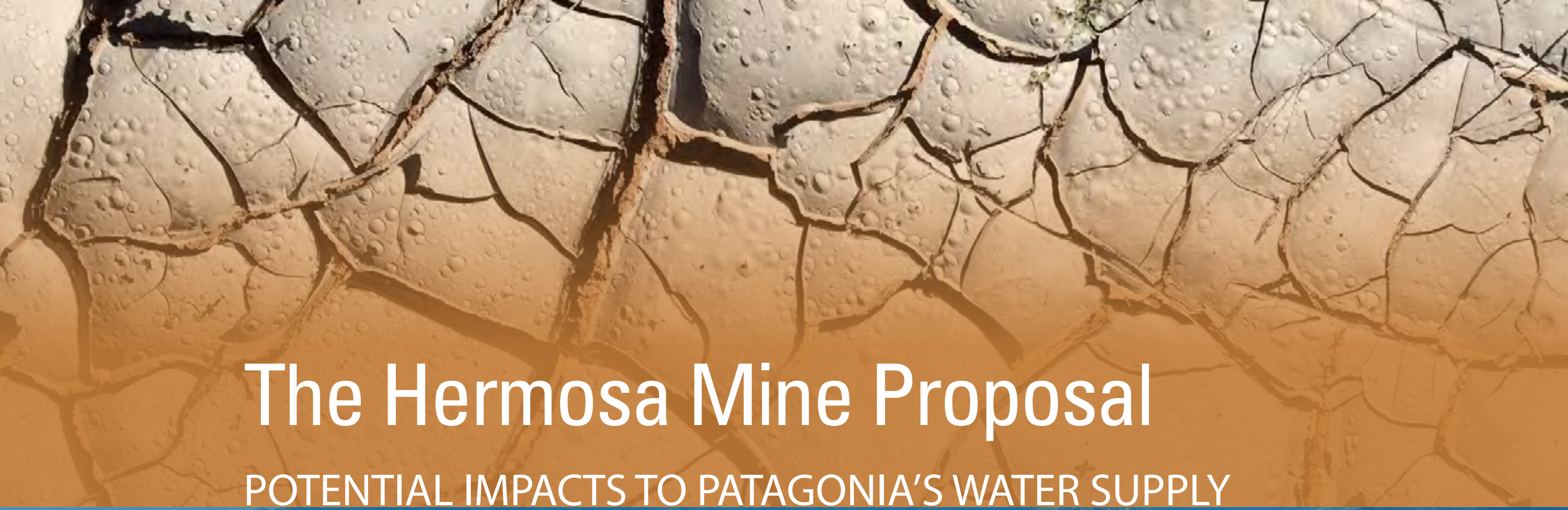

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## POTENTIAL IMPACTS TO PATAGONIA'S WATER SUPPLY

OCTOBER 2014

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Earthworks and The Patagonia Area Resource Alliance
Report available at: hermosareport.earthworksaction.org

Cover photo: The Patagonia Mountains, near the site of the proposed Hermosa Mine.
Cover and scenic photos by Gooch Goodwin, goochgoodwin.com.

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*For 25 years, Earthworks has been protecting communities and the environment from the impacts of irresponsible mineral and energy development while seeking sustainable solutions.*

Patagonia Area
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*The Patagonia Area Resource Alliance is a grassroots, non-profit community alliance committed to preserving and protecting the Patagonia, Arizona area.*

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# Executive Summary

The 4,000-foot wide and 1,500-foot deep open-pit silver and manganese mine proposed by Wildcat Silver in southeastern Arizona, six miles from the town of Patagonia, threatens both the quantity and quality of area water supplies.

Using geologic and hydrologic studies from project developer Wildcat Silver, the United States Geologic Survey, the Arizona Department of Water Resources, the town of Patagonia, and others, and by analyzing historic contamination issues caused by mining in the Patagonia Mountains, Perpetual Impact explains how:

- Patagonia is already facing a water supply crisis and new industrial water demands will make the problem worse.
- Private and municipal water well levels in Patagonia are dropping rapidly, and some have already gone dry. Rationing may be soon become necessary.
- The groundwater the mine would pump for operations is within Patagonia's municipal supply watershed. The mine's consumption will lower recharge rates for the aquifer on which the town depends, potentially depleting it.
- As proposed, the mine would consume between 670 million and 1.2 billion gallons of water every year – 28 to 53 times more water than consumed by the entire town of Patagonia, and as much as 25,000 to 46,000 Arizonans.
- After the mine is closed, a lake containing billions of gallons of water will form in the abandoned mine pit, further increasing groundwater depletion in the adjacent aquifers as the lake forms. Evaporation from this pit lake will annually consume groundwater at a rate comparable to when the mine was in operation, yet it will occur forever.

**Consuming 670 million to 1.2 billion gallons of water every year – as much as 25,000 to 46,000 Arizonans – the mine would lower Patagonia's aquifer recharge rates.**

The geology of the deposit virtually guarantees that the mine's waste will cause acid drainage and metals leaching to contaminate water in perpetuity – an expensive and ever-lasting problem often paid for by taxpayers.

- Most mines in the Patagonia Mountains continue to leach acid today, despite the fact that operations ceased over 50 years ago. Many of the area's seasonal creeks are locally contaminated, and so is the groundwater beneath them.
- Because the Hermosa Mine would move 1,679 times more rock than the largest of these past mines, its long term contamination legacy would be far more impactful than anything experienced in the past.
- Because previous studies have shown that groundwater flows down the drainage in which the mine is proposed, there is risk of contamination by acid, heavy metals and sulfate in water wells below the mine site, potentially as far as Patagonia.
- A large tailings impoundment holding toxic mine waste could catastrophically fail and dump millions of tons of contaminated sediment into the creek valley that leads to town. Three similar accidents have already occurred in North America in 2014 alone.

## The proposal has numerous other impacts:

- It may consume as much electricity as over 35,000 Arizonans, burn 9.3 million gallons of diesel fuel each year, and emit 591 million pounds of carbon dioxide pollution annually – equivalent to 71,000 cars.
- Light and noise pollution would be a constant reality for the 18 years the mine is projected to operate.
- The widening of Forest Service roads and numerous other types of infrastructure development will affect existing recreational uses and residences near and beyond the mine site.
- Wildlife is likely to be negatively affected as area springs run dry to due groundwater depletion.

**Water pools in the Patagonia Mountains, near the proposed Hermosa Mine.**
Photo by Gooch Goodwin.

# Introduction

This report was written to help bring clarity to the ongoing public dialog regarding the environmental impacts – particularly regarding water – of the proposed Hermosa Mine in southeastern Arizona's Patagonia Mountains being advanced by Wildcat Silver – a Canadian junior mining company. It offers basic definitions of these impacts and contextualizes them through applicable case studies. By analyzing known, site-specific information about the mine, such as its geology and hydrology, the report explains why these impacts are likely to be experienced at the Hermosa Mine both during its life and far beyond.

Our goal was to assess these risks in a format brief enough to be realistically digestible to non-experts. One of the problems with civic debates of large, complex mine proposals is that the most pertinent information regarding environmental risks is often buried within numerous technical documents hundreds, if not thousands, of pages long.  While necessary for mine engineers, geochemists, government permitting agencies, and others, these documents are not written with the stated purpose of informing civic debate, but rather to guide the project through its development process. Though this report is rooted in these types of documents, it was written for typical stakeholders trying to make sense of the facts.

Although proponents of this report may argue elsewhere that the likely impacts are unacceptable, the motivation to write it was not brought on by the desire to make that case, but rather to make it easier for people to come to their own conclusions based on the most accurate information available. While we believe the risks are quite serious and form the basis of this report, we also understand that some may generally consider known benefits of large mines – such as tax revenue – to be more important than environmental preservation and long-term water security. Our hope is that this report can be used as a tool to help weigh these tradeoffs as objectively as possible, and steer the dialog away from the classic 'them versus us' dialog and into the realm of tangible realities that affect all stakeholders.

The main purpose of the report is to characterize the nature of groundwater depletion and potential water contamination. We will look closely at the amount of water mines of similar size and design use, and put it into the context of the proposed mine. We will evaluate the nature of acid mine drainage, the permanent and active management it requires, its tremendous cost, as well as what happens to the environment when the drainage goes untreated. We'll provide an overview of the likely connection between groundwater at the mine site and within Patagonia, and give examples of places where people have been affected by groundwater contamination caused by large mines.

We will also look at energy requirements and carbon emissions, quantify the mine's physical footprint on the land, and analyze other potential long-term pollution liabilities. Finally, we'll look at cumulative impacts, including infrastructure and possible mine expansions, and assess the nature of tailings dam failures with a few case studies.

Information about the details of the proposed Hermosa Mine are largely sourced from within the pages of a Pre-Feasibility Report[1] (PFR) written in early 2014 by M3 Engineering and Technology Corporation, a Tucson, Arizona-based environmental consulting firm hired by

Wildcat Silver. Additional information throughout this report cites earlier studies, including a 2012 Preliminary Economic Assessment as well as academic papers produced by various universities, the United States Geologic Survey, mine data websites, and many other sources.

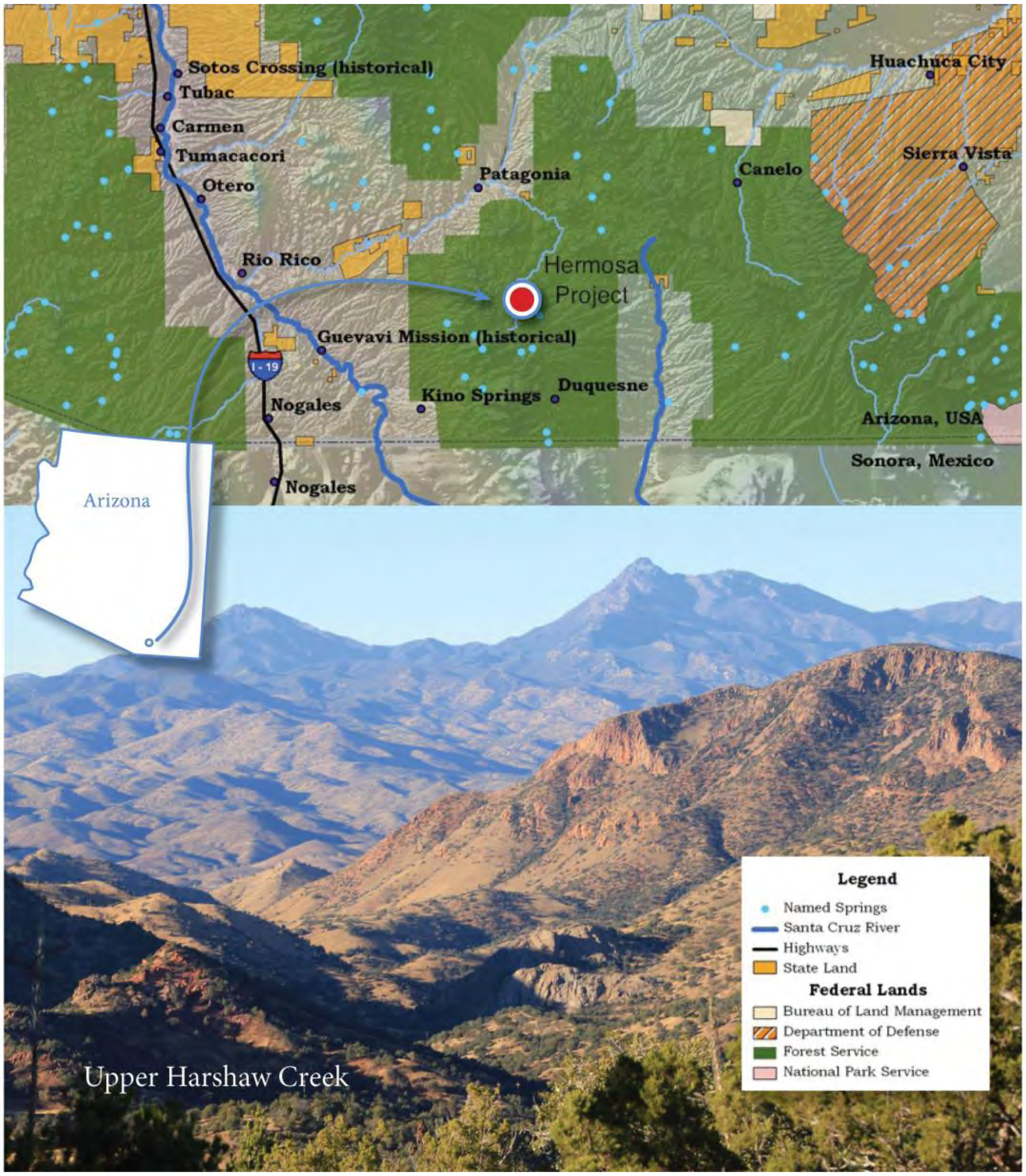
**Note on references**: Because some documents are not available online from their original sources, some cited materials have been uploaded to the Patagonia Area Resource Alliance's website to make them available to the reader. All links are listed in the references chapter at the end of the report.

**Note on conversions:** This report relies on many sources, some of which do not distinguish between short tons and metric tons, the latter is roughly 10 percent more weight than the 2,000 pound short ton used in the United States. Some minor discrepancies may exist as a result.

**Note on mine name:** The project is considered the "Hermosa Project" by its developer, Wildcat Silver. For simplicity, we refer to a future mine at this site, under the existing plans set forth by Wildcat Silver, as the "Hermosa Mine" even though this is not a formal proper name at this point. A future name for the mine may change over time, as may the details of the mine proposal.

# Patagonia and its Watershed

Patagonia, population 913 in 2010, is located near the confluence of Harshaw Creek and Sonoita Creek, about 14 linear miles from the Mexican border and 18 miles from the border town of Nogales. Because these creeks and most others in the area are either seasonal or their flows vary greatly, the town relies on groundwater wells for reliable supply. Upper Harshaw Creek is the site of the proposed Hermosa Mine, and during the monsoon season (late summer and early fall), the creek flows towards town, where it joins with Sonoita Creek just upstream of downtown Patagonia. Sonoita Creek continues southwest and flows into an artificial reservoir.



**This watershed map shows the confluence of Harshaw and Sonoita Creeks at the town of Patagonia, and the Hermosa Project within the headwaters of Upper Harshaw Creek (source[f]).**

**Photo from the Patagonia mountains, looking northwest from a hillside above the Harshaw Creek Drainage. The peaks in the distance are part of the Santa Rita Mountains.**
Photo by Pete Dronkers, Earthworks.

## Mining History

Small-scale miners have been operating in the Patagonia Mountains since the 1860's and their tailings and waste rock piles can be seen throughout the range. There are roughly 130 abandoned mines in the mountain range, most of which were quite small by today's standards. Virtually all were underground operations using shafts and tunnels. Mining in the Patagonia Mountains ceased in the mid-1960's. To this day, only three of the 130 mines have experienced planned reclamation efforts, some of which remain ongoing.

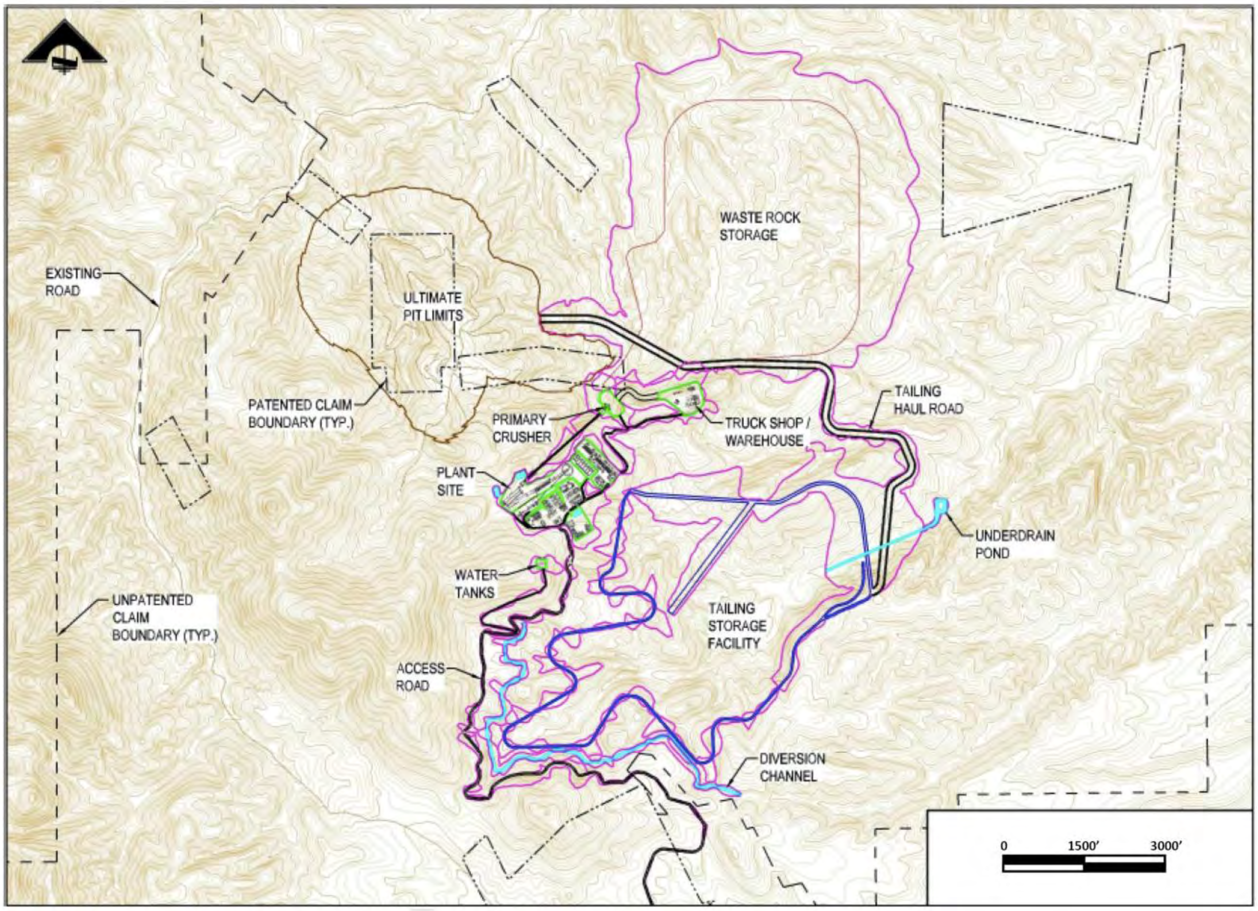
The largest of these historic operations was the Trench/Josephine Mine Group, which produced a total of 237,000 tons (source[2]) of ore over two separate periods from the late 1850's to 1945, totaling about 70 years of production. However, most individual mines – especially the older ones – operated for decades and only produced a few thousand tons of ore. By comparison, the proposed Hermosa Mine is expected to process 60 million tons of ore from its open pit during 18 years of operation. Additionally, it would also remove 338 million tons of waste rock, for a total of 398 million tons of rock removed from the pit. This volume is 1,679 times the amount of production from the largest of Patagonia's historical operations, and 187.5 times the amount of historical production from every mine in the northern Patagonia Mountains (Harshaw Mining District) combined (source[3]).

**There are roughly 130 abandoned mines in the region – all had ceased operations by the mid-1960's. To this day, only three of the 130 mines have experienced planned reclamation efforts, some of which remain ongoing.**

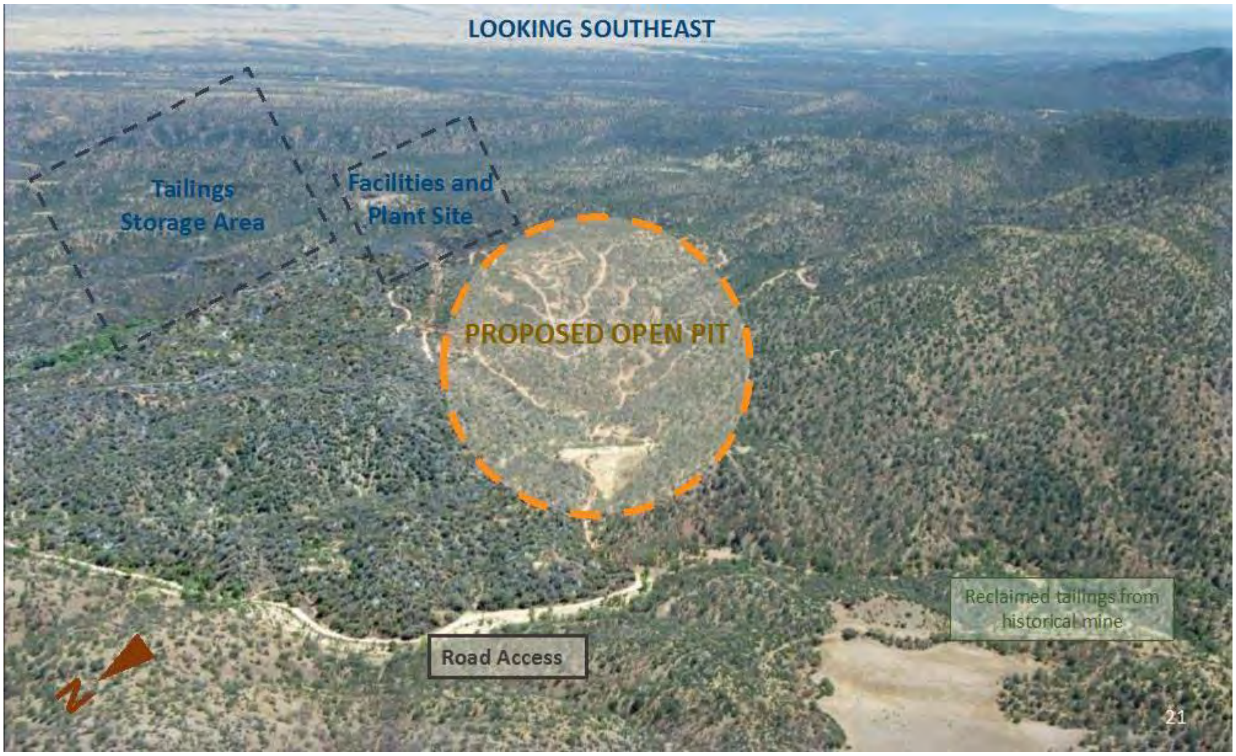
**The Patagonia Mountains during the late summer green season, from Red Mountain, looking south.**
Photo by Gooch Goodwin.

# Overview of the Mine Proposal

The Hermosa Mine would become, by far, the largest industrial operation within about a 27 mile radius of Patagonia. Currently, the closest large mine is the Sierrita Mine near Green Valley, northwest of Patagonia. The Hermosa project is located within the Coronado National Forest, approximately 6.3 linear miles southeast of Patagonia. A total of 13,668 acres, or 21.3 square miles (PFR, pp. 26) are claimed by Arizona Minerals, Inc, a majority owned subsidiary of Wildcat Silver.



**Mine plan according to the 2014 Pre-Feasibility Report. The overall mine footprint would be approximately 3.5 square miles.**



**Mine site according to Wildcat Silver's Investor Presentation, April 2014. The mine site is approximately 6.3 linear miles southeast of Patagonia.**

**The town of Patagonia with Red Mountain above.** Photo by Gooch Goodwin.

**Closer view of pit location, showing exploratory roads built for drill rig access. The ultimate pit limit would extend beyond the roaded areas in this image.** Photo by Pete Dronkers, Earthworks.

The Hermosa open pit would be approximately 4,000 feet from its north to south rim, and slightly wider from east to west (PFR, p. 122). The highest point on the rim of the pit would be 5,625 feet above sea level, the lowest point at 5,045 feet, and the ultimate pit depth would be 4,060 feet above sea level – the same elevation as Patagonia. Therefore, the maximum pit depth (and height of the tallest pit wall) would be 1,565 feet deep (PFR, p. 122). The elevation of the current water table is at 4,950 feet.

Because most of the rock removed from the Hermosa pit is not rich enough in target minerals to be processed (5.7 parts waste per part of ore), it will end up as waste rock to be placed in large, permanent dumps called Waste Rock Storage Facilities – a misnomer because this rock will be permanently dumped rather than stored for later removal. In later chapters we will look at why these waste rock dumps can cause water contamination. Rock containing economically recoverable quantities of metals (ore) will be sent through a crusher at the rate of 13,700 tons per day, or 5 million tons per year, and through a series of milling circuits. The waste from the mill – known as tailings – will report to the Tailings Storage Facility, also a misnomer because the tailings is a permanent dump rather than a storage facility. Most tailings waste is a powder-like material with particle sizes measured in microns (1/1000th of a millimeter).

**THE BASICS**

- **Pit length and width: approximately 4,000 feet x 5000 feet, or 4/5 mile x 1 mile**
- **Maximum depth of pit: 1,565 feet**
- **Total rock removed from pit at the end of mine life: 398 million tons**
- **Ratio of waste rock to ore that will be milled: 5.7 parts waste rock per part of milled ore**
- **Rock crushed and sent through the mill per day (mill throughput): 13,700 tons**
- **Difference between current groundwater level and bottom of pit: 890 feet**
- **Estimated volume of pit lake after mine closure: 10-20 billion gallons**
- **Mine life: 18 years**

The mine's productive life is 18 years, comprising ten years of pit mining and milling, followed by eight years of milling stockpiled ore. However, at the front end, site preparation, infrastructure build out, and mill and building construction may add to this projected 18 year time frame. In addition, some reclamation may follow the end of productive life, further adding to the timeframe. Finally, because the mine will almost certainly require water treatment in perpetuity, most likely requiring a warehouse-sized treatment plant, the mine will have a presence in the Patagonia Mountains essentially forever.

**The Thompson Creek Mine in Idaho, an operation comparable in size to Hermosa. Although this mine processes more ore per day, the ultimate depth and width of the pit is similar: 1500 feet deep and 5,000 feet across (source[a]).** Photo by Thompson Creek Metals.

**Waste rock dumps surrounding the Bingham Canyon Mine, Utah.** Photo by Earthworks.

# Water Requirements

During operation, hardrock metal mines are among the highest industrial consumers of water. The largest amounts are used during the milling process, as pulverized rock is turned into slurry by adding water and chemicals and sent through various mill circuits. After mineral extraction, the vast majority of remaining slurry, usually over 99%, is sent to the tailings dump via pipeline (aqueous tailings) where water is lost to evaporation or, less often, by conveyor belt (dry stack tailings) – two methods we will discuss later. Other water intensive processes include dust control, cooling associated with electricity generation, and any process that releases steam into the air.

After mine closure, many open pit mines form very deep lakes containing large volumes of water. As we will explore later, in the case of Hermosa this may amount to more water than the mine would use during it's entire life. Before mining, the ground is mostly solid rock with perhaps 1% being "pore space" which may contain water. After mining, a portion of the pit (the size of the lake is determined by many factors) becomes 100% water. This water comes from adjacent aquifers as the lake fills over time; this is water that in the absence of a mine would remain in the ground and accessible to people. Meanwhile, evaporation from the surface of the pit lake contributes to water loss forever, and the larger the pit lake grows, the more evaporation occurs. While longer term, these dynamics must be taken into account, as their hydrologic repercussions are equally severe, if not more so, than water lost during mine operation.

**Aqueous tailings dump at the Goldstrike Mine, Nevada.** Photo by Earthworks.

This report aims to estimate consumptive losses at the Hermosa Mine during its life as well as estimate longer-term losses. We define consumptive loss as water lost from the local hydrologic system and not returned to it, most notably through evaporation and steam releases but also including the filling of a lake which didn't exist prior to the mine. Water that is recycled or percolates back into groundwater at the mine site is not considered consumptive loss. In comparisons to other types of water use, this same approach is taken to maintain accurate estimations regarding how much water a particular sector actually consumes, rather than simply pumps from one point to another. For example, while municipal water manager may pump hundreds of acre feet to a small town's water distribution system, much of that water is either returned to the ground through septic leach fields or to a municipal water treatment plant where it is recycled. The same may apply to agricultural operations where a portion of irrigated water returns to underground aquifers.

A significant factor that determines the water requirements of a large hardrock mine is the way tailings are processed. Some mines – especially newer mines in water-constrained environments – utilize "dry-stack" tailings systems. This system adds smaller amounts of water (usually less than 15% of the final mixture consists of water) to the spent ore and sends damp tailings to an engineered dump by conveyor belt, were it is then spread around and compacted by heavy machinery.

With a conventional aqueous tailings dump such as the one proposed at Hermosa, however, the tailings mixture contains significantly more water – usually, roughly 40%, rather than 15% for dry stack operations. This enables tailings slurry to be transported to the tailings dump by pipeline rather than conveyor belt and eliminates the need for machinery to spread around and compact the tailings – both of which can reduce operating costs for a mining company but greatly increase water consumption.

Much of the water consumption at Hermosa during its operation will be attributed to mill processes and evaporation at its tailings dump. Slurry pumped to the dump containing roughly 40% water will collect at the surface of a tailings impoundment, as seen in the above and below photos, where it would bask in the Arizona sun and disappear into the atmosphere. Also, other mill processes can be water intensive as well, releasing large amounts of steam and therefore representing a consumptive loss. As we will examine in more detail later, after closure, the filling of and evaporation from Hermosa's permanent pit lake will constitute comparable losses forever.

Another factor in water consumption is electrical generation. Whether occurring on or off site, both must be factored into water use calculations. As we will see later in the report (in the energy consumption chapter), the Hermosa mine would be a large energy consumer, drawing an estimated 20 megawatts of electricity – the same as 35,000 Arizonans. It is likely that most of this demand would be met from coal and/or natural gas fired power plants, which require large amounts of water to cool turbines – much of which is lost as steam.

**The Twin Creek Mine, Nevada, showing steam releases and consumptive water loss at the mill. The aqueous tailings dump, beyond, evaporates large amounts of water as well. It is likely red from the oxidation of waste minerals.** Photo by Earthworks.

Wildcat Silver has filed for permits to begin a geotechnical and hydrogeological drilling program, partially to better understand water supply issues at the mine site. However, it is stated within the PFR (pp. 32) that "available well information suggests adequate water supplies are available for project requirements." Despite the PFS having extremely detailed mill process and economic benefit analysis, it contains no substantive information regarding the adequacy of intended water sources to meet demand beyond this statement. This lack of analysis is impressive. Considering that water supply is one of the most important factors when assessing the feasibility of a mine, it is worth noting that Wildcat's Prefeasibility Study includes only one sentence on the topic while other issues, such as the projected financial return on investment, is given perhaps one hundred pages.

According to a 2010 Preliminary Economic Assessment (PEA, source[4]), the mine plans to use a series of five wells at the mine site, as well as water removed from the pit, to supply its needs, with about half of the supply coming from each source. The latter occurs because much of the pit will be deeper than the groundwater table. The pit walls and the bottom of the pit will seep and water will collect within it, and must be pumped in order to conduct mining operations. Rather than discharging, this water will be treated and utilized for various processes.

The PEA did, however, provide a basic methodology (pp. 120) to help calculate water needs:

> *The volume required is calculated as one-half of water for each ton of ore processed. This is an accepted rule of thumb for mining operations in arid regions…*

Using this methodology based on a known mill throughput of 13,700 tons per day, water consumption at Hermosa would be 6,850 metric tons of water, or 134 gallons per ton of milled ore.

To help create a better estimate, data from existing hardrock mines in Arizona with conventional, aqueous tailings dumps can be used. Although the mines below are copper mines, we can see a similarity in water consumption. The chart below shows annual water consumption averaged between 2004 and 2008 (source[5], pp. 6).

| Mine | Daily mill throughput | Average water use per year 2004-2008 | Water use per ton ore |
|---|---|---|---|
| **Bagdad** | 77,000 tons/day | 14,840 acre feet/year | 172 gallons/ton |
| **Mission** | 41,000 tons/day | 8,528 acre feet/year | 185 gallons/ton |
| **Morenci** | 54,000 tons/day | 13,120 acre feet/year | 216 gallons/ton |
| **Ray** | 30,000 tons/day | 14,460 acre feet/year | 430 gallons/ton |
| **Sierrita** | 102,000 tons/day | 27,110 acre feet/year | 237 gallons/ton |

As the above data show, Wildcat Silver is using methodology that suggests the Hermosa Mine will be significantly more efficient with water than many of Arizona's existing mines. Because these data are relatively recent, it is reasonable to believe that these mines have already implemented water conservation and efficiency measures beyond what was possible several decades ago. And because Hermosa is utilizing comparable mining methods and an aqueous tailings dump, claims that it will be more efficient than these other mines should be closely scrutinized should the mine proposal continue to advance towards permitting and development.

Using Wildcat's own estimation of 134 gallons per ton, water consumption during mine operation would equal:

- 1,835,800 gallons per day (5.63 acre feet)
- 670 million gallons per year (2,056 acre feet)
- 12 billion gallons over the life of the mine (37,014 acre feet)

However, if the average for existing mines in Arizona is more accurate, at 248 gallons per ton of ore, Wildcat's water consumption during operation would be:

- 3,397,600 gallons per day (10.4 acre feet)
- 1.2 billion gallons per year (3,805 acre feet)
- 22 billion gallons over the life of the mine (68,504 acre feet)

An Olympic swimming pool contains about 660,430 gallons of water (source[6]). Every year during mine operation, the Hermosa Mine would consume between 1,014 and 1,816 Olympic pools worth of water, and nearly that much every year forever due to evaporation from the pit lake which would form after mine closure. (source[7])

**The Hermosa Mine would consume about 1,000 to 1,800 Olympic swimming pools worth of water per year during operation, then continue to lose nearly that much every year forever due to evaporation from the pit lake which would form after mine closure.**

By comparison, according to the United States Geological Survey, the average Arizonan withdrew 140 gallons per day in 2005 (source[8]). However, much of this water is recycled or returned to groundwater through residential or commercial leach fields, municipal water treatment and recycling centers, or through percolation to groundwater from landscape watering. According to Wateruseitwisely.com (source[9]), at least half of all residential water in the state is used for landscaping. Most of the rest is used within the house and does not necessarily represent a consumptive loss for the reasons mentioned above.

For the sake of simplicity, we'll estimate that only about half of residential water pumping actually represents consumptive loss (all landscaping water use), although we have spoken with municipal water managers that estimate consumptive loss on the municipal level in the southwest to be closer to only 30% of the total withdrawn amount. Regardless, at a 50% rate of consumptive loss, 70 gallons per person per day is consumed. Patagonia's population in the 2010 census is 913, so the town's residents consume 63,910 gallons per day. The Hermosa mine would therefore consume between 28 and 53 times the amount of water needed by all of the town's residents combined.

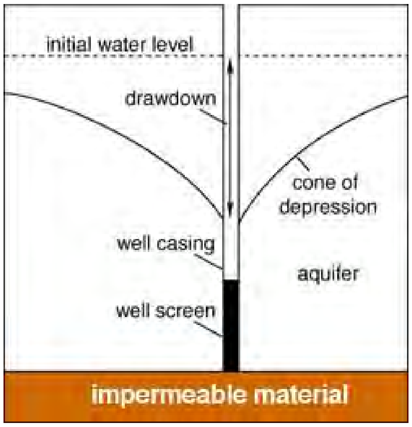
Another comparison uses data from Patagonia's municipal water distribution system. Between 2008 and 2013, the average annual water quantity pumped from the town's water supply well was 42.5 million gallons, or 116,674 gallons per day (source[10]). Using the same rationale regarding consumptive loss versus total water pumped, we arrive at a similar number of 58,337 gallons per day, or 63 gallons per person per day.

It is important to note that the above calculations do not include consumptive water loss from power generation commissioned to meet the mine's electricity needs. According to the US Environmental Protection Agency (source[11]), thermoelectric power generation accounts for 41.5 percent of total water withdrawals in the United States, much of which represents consumptive loss associated with cooling units that release steam. As we will see later, the mine may require roughly 182,000 megawatt hours of electricity per year. According to a study (source[12]) by the Arizona Water Institute, coal fired power plants consume 510 gallons of water per megawatt hour of electricity.

Most likely, the Hermosa Mine would derive its power through a grid connection to the Sulphur Springs Valley Electric Cooperative (although depending on unknown factors, could be an adjacent electric provider), which distributes electricity generated by coal. Therefore, an additional 92 million gallons (285 acre feet) per year is added to the total water consumption number, although this consumption will occur elsewhere. This added water use accounts for between 7% and 13% of additional consumption depending on the ranges presented in the above analysis.

## The nature of mine dewatering and the cone of depression

Now that we've estimated a range of water volumes the Hermosa Mine would consume, a discussion regarding the nature of the impacts is warranted. As mentioned earlier, because the pit will be 890 feet deeper than the current static groundwater level, it will need to be pumped dry so mining operations can occur. This pumping, as well as the other half pumped from deep wells elsewhere on the property to supply the mine's needs, creates a "cone of depression" (or similar shape) where the groundwater level takes on the general shape of a cone rather than a table, as illustrated below for a water well (source[13]). Large mines are known to create cones of depression that can reach dozens of miles away from the mine site.



At Nevada's Goldstrike mine, dewatering resulted in a 1,200 foot drop of the water table around the mine site by 1994 (source[14]) (source[15], p. 33). Projections for the size of the cone of depression at the proposed Rosemont Mine near Tucson vary, but according to a study by Dr. Waite Osterkamp released by the Sonoran Institute, dewatering could impact groundwater resources up to 25 miles to the east and southeast of the mine pit. (source[16]). Hydrologists believe that the Rosemont mine will render dry some 60 springs in the mountain range, as well as impact Las Cienagas National Conservation Area and numerous private water wells within the cone (source[17]). The references above include other case studies of groundwater drawdown at open pit mines as well.

At Hermosa, with mining occurring to 890 feet below the current groundwater table, a cone of depression of comparable depth will very likely form. The regional extent of the cone, its shape, and the pumping rates to dewater it will require much more study to estimate, but even those estimates may be uncertain. For example, the Goldstrike Mine had originally predicted that dewatering rates would be around 28,000 gallons per minute, but within two years the mine was pumping more than twice that amount (source[18]) due to the interception of a fault which carried water from a long distance away to the pit. Indeed, geologic factors can determine the shape and extent of a cone, but generally, the more water removed from a pit, the larger the cone of depression will be.

In the case of Hermosa, if estimations for dewatering prove to be too high, with actual pumping rates lower than expected, the mine will compensate to meet its water needs by taking the difference from its deep groundwater supply wells. If the amount is too low, the mine will take more from the pit, and less from the supply wells. Either way, the water will come from the ground at and adjacent to the mine site. If a fault system(s) is intercepted, this could increase the reach of groundwater depletion in the direction of the fault. Conversely, in the absence of porous material on one side of the pit (which is unlikely), drawdown on that side could be less pronounced than the other side.

Depending on the regional hydrogeology, dewatering the Hermosa pit and pumping from its supply wells could propagate some distance away from the mine site, with potentially detrimental consequences to springs and wells currently used by the local community (with the former being used by wildlife as well). Even if Patagonia does not end up within a defined, homogenous cone of depression, it could experience groundwater depletion due to the heavy dewatering of the Harshaw Creek headwaters which recharge a significant portion of Patagonia’s groundwater supply via the shallow aquifer in the drainage (this aquifer will be discussed later). Regardless of the findings from different approaches to hydrogeological modeling, one thing is clear: between 670 million and 1.2 billion gallons of water per year will entirely disappear from the hydrologic systems of the Patagonia Mountains and more specifically, the upper Harshaw Creek area, every year during the life of the mine. In addition, a comparable amount will be lost in perpetuity due to the filling of the pit lake and evaporation from it. While the extent and depth of the cone of depression cannot be precisely known in advance, there is little doubt that there will be significant groundwater depletion, and that depletion will generally manifest itself closest to the mine site first, then propagate outwards depending on hydrogeological conditions. This depletion is likely to affect the fluvial aquifer along Harshaw Creek, though the extent to which that could happen will require more study to ascertain.

## Pit lake filling and evaporative loss

In theory, if the pit were immediately dug to its ultimate depth and then quickly filled with water to the level of the current groundwater table, it would form a lake 890 feet deep (but still not high enough to breach the lowest point on the pit rim). However, as we will see below, the pit will not fill to this pre-mining level in reality because of evaporation from its surface, and will instead form a smaller lake. Although precise calculations for the volume of the pit lake are not within the scope of this study, if the lake contained a volume of water equal to a cylinder 1000 feet in radius and 450 feet deep (this is likely a conservative estimate, as this is a fraction of the volume of the pit that lies below the current water table), it would contain 10.5 billion gallons of water. By comparison, our calculations for consumptive water loss for the entire 18-year mining period range from 12-22 billion gallons. Therefore, as the pit lake fills over time, it may ultimately draw a comparable amount of water into the pit as was consumed during most of the mine's operational life.

A major factor influencing the rate at which the pit lakes fills, the level it ultimately reaches, and the perpetual water loss it causes is evaporation from the surface of the pit lake. As mentioned, the pit will not fill to pre-mining groundwater levels in reality because evaporation represents a net water loss. In other words, the surface of a pit lake acts much like a large active water well, in that water is being removed (through evaporation) at a relatively constant rate. Studies by Tom Myers of pit lake hydrology in Nevada's Humboldt River Drainage (source[19]) showed that in some cases, pit lake evaporative loss is so severe that the cone of depression is expected to continue expanding long after mine closure, and that a return to pre-existing groundwater levels and conditions will never occur. A steady lake level will eventually be that in which pit infiltration and rainfall combined equal evaporation, but even when this point is reached, a cone of depression will still exist. At Hermosa, this scenario is likely; even if the pit partially fills with water, there may never be a complete recharge of groundwater to levels that existed before the mine. Drought in the southwest will exacerbate the problem – both by increasing evaporation rates and by decreasing groundwater infiltration – resulting in a longer period of time to reach a steady lake level as well as a lower lake level than would be the case in non-drought conditions.

**Closed pits and lakes near the Mission Mine Complex, southeast Arizona. For scale, the benches on the right hand photo are probably between 25 and 35 feet high.** Photo by Pete Dronkers, Earthworks.

In southeast Arizona, evaporation rates for standing surface water far exceed precipitation rates. Therefore, any standing water represents a net water loss. According to the Arizona Division of Water Resources (source[20]), an evaporation rate monitor located between Rio Rico and Nogales, about 15 miles southwest of Patagonia, recorded average annual evaporation rates of 91.2 inches between 1952 and 2005. Precipitation is only about 17 inches (source[21]), though during drought it is less.

ADWR recommends multiplying the evaporation rate by 0.7 or 0.8 to reflect the actual evaporation rate that would be experienced in a lake setting. Because the Hermosa mine's pit lake surface at today's groundwater levels would be approximately 1,400 feet higher in elevation than ADWR's evaporation monitor (and therefore slightly cooler), we will use the lower multiple to arrive at 63.84 inches of annual evaporation.

Roughly calculating the pit lake size to be 0.75 square mile in surface area, or 480 acres, annual evaporation would be 2,553 acre feet per year. This is equal to 832 million gallons per year, every year, forever. Therefore, even after closure, the Hermosa Mine pit lake would result in a perpetual water loss comparable to the years of its operation, with hydrologic implications that could be equally severe to those experienced during the life of the mine. Whether being caused by pit dewatering and supply well pumping during the life of the mine, or simply by evaporation, after it is closed, the Hermosa Mine will consume water from the start of mining into perpetuity.

## Patagonia's current drought and water crisis

Patagonia and many other parts of Arizona are facing serious water supply issues. Groundwater levels have been steadily dropping for the last decade, and Patagonia water managers are growing increasingly concerned about the well levels and pumping rates required to meet the town's demands. Hydrologists attribute these realities to the ongoing drought as well as overuse of southeastern Arizona's groundwater by agriculture, the mining industry, power generation, and cities.

Recent news articles showcase the severity of the situation. In a February 2014 article (source[22]), the Patagonia Regional Times reported:

> *Patagonia's water well levels are at an all time low and have been so for the past three months. Town Manager David Teel has recommended that the town declare a water alert and will begin discussion with the town council during the next few weeks as to when and how to begin implementing water use restrictions…*
>
> *In accordance with the town's drought emergency plan, residents will be asked to reduce their water use by as much as 50% and to limit outside watering to only that which is essential. A watering schedule may be enacted, limiting outside water use to certain days…*

Pumping data for Patagonia's wells over the past six years indicated that the depth to which the pumps must go to access water has gone from an average of 21.7 feet in 2008 to an average of 39.4 feet in 2013 (source[23]).

Also in February 2014, the Weekly Bulletin ran a story about the water crises, quoting Mr. Teel as saying "Our population is the same, and we are pumping the same amount [in 2014 as that of 2008]. Maybe someday it will rain again and the water will go back up." (source[24])

According to a May, 2014 Nogales International article entitled "With wells running dry, residents call for help," (source[25]), since November 2013, six wells in a neighborhood 13 miles south of Patagonia have run dry.

In addition to these wells, others in Patagonia have experienced rapidly diminishing well levels while others' have gone dry. In an April, 2014 letter from the president of the Red Rock Acres Homeowner's Association, residents were informed that the adjacent Linder subdivision water well had gone dry, forcing it to purchase water from the town at significant cost (source[26]). The Red Rock HOA well itself also experienced a 14 foot drop in as many years. Michael Stabile, a Patagonia resident, bought a house with a 36 foot deep dug well used for irrigation. In 2009, the water level was at 16 feet but today the well is completely dry. Patagonia residents Lee and Ann Katzenbach also experienced recent problems with their 200 foot deep well and decided to drill a new one, in which water was not found until nearly 700 feet.

Although well depths and depletion rates clearly differ, well levels are generally dropping rapidly in and around Patagonia, far beyond seasonal fluctuations, rendering wells dry and leaving residents in difficult situations. The Hermosa Mine would use between 28 and 53 times the amount of water the town currently uses, and as we will see in the next chapter, the groundwater on which the town depends is recharged significantly by the Patagonia Mountains. And with that comes a pathway for contaminants to spread to it as well.

## The Patagonia Municipal Supply Watershed and Isotope Tracer Studies

As we have seen previously in this report, water consumption is a major concern for the proposed Hermosa Mine, but water contamination is equally consequential. Both of these concerns were the driving force behind a citizen-initiated effort to designate the Harshaw Creek drainage as part of a broader Municipal Supply Watershed in the management plan for the Coronado National Forest. Currently the plan is in draft form, with the Patagonia Municipal Supply Watershed penciled in. According to the Coronado National Forest, the agency is not planning to remove the proposed designation in the final plan. The draft management plan describes the watershed below (source[27]):

> *The 128,000-acre Sonoita Creek Watershed is a municipal supply watershed. Sonoita and Harshaw Creeks and their subterranean aquifers provide the only source of potable water for the Town of Patagonia with over 900 residents and over 300 private well users within a 3-mile radius of town. The shallow depth of the aquifers combined with the nature of the soils and underlying geology make the relationship between the surface and ground water watersheds a particularly close and interconnected one.*

This description alludes to what hydrologists have concluded about the Harshaw Creek drainage; that it is filled with alluvial gravels and sands that conduct water downhill until it mixes with groundwater associated with Sonoita Creek at Patagonia. It is another indication that water falling as rain from upstream sources does indeed serve to recharge groundwater which then flows downhill to the town's wells.

This is supported by an isotope tracer study (source[28]) within the larger Sonoita Creek Basin. In this study, hydrogeologists examine a chemical's "signature" by analyzing various isotopes unique to a certain area. These chemicals are contained within groundwater, and in this case sulfate isotope concentrations were measured throughout the watershed. If downstream isotopic analysis matches the upstream analysis, a connection is established. The study included a sample location within the Harshaw Creek Basin, as well as one above the confluence of Sonoita Creek and Harshaw Creek, and one below the confluence. Isotopic analysis below the confluence more closely matched that of the source within the Harshaw Creek drainage, indicating a significant contribution of Harshaw Creek groundwater to the Sonoita Creek Basin, the source of Patagonia's municipal water supply. Water above the confluence did not contain similar isotope concentrations, allowing researchers to eliminate other possible water sources and identify a particular area within the Harshaw Creek drainage (Red Mountain) as the most likely source of sulfate tracers.

The isotope tracer study and the Forest Service's description both indicate that the groundwater originating within Harshaw Creek feeds the groundwater below Patagonia, and travels there through the alluvial materials within the drainage. Therefore, it is not difficult to predict how contamination originating at the mine could migrate to wells below it. As we will see in the next chapter, the most widespread and consequential type of mining pollution is acid mine drainage, yet many other types of contamination can also impact water quality, such as nitrates, cadmium, arsenic, mercury, lead, zinc, and spills from chemical and fuel lines or storage containers throughout a mine property.

There is also a chance that acid mine drainage and other contaminants could percolate deep under the mine site – even as the area is dewatered – and follow underground pathways deeper than the alluvial gravels within the Harshaw Creek Drainage. Any connections between these underground hydrologic pathways and the alluvial aquifer on which the town and neighboring residents depend – such as faults or interconnected cracks or fissures in the bedrock – would jeopardize the water quality of the shallow aquifer and everyone who has a well drilled into it near or downhill from where those connections occur.

This report cannot be truly conclusive about specific groundwater pollution dynamics. A comprehensive hydrogeologic study based on open pit impacts will be needed to model the possible outcomes – and even then, some degree of uncertainty will undoubtedly remain. Our goal in this chapter was not to attempt this level of analysis, but rather to illustrate the nature of Harshaw Creek's alluvial aquifer and potential contaminant pathways along it, and to indicate that deeper hydrologic pathways can also serve to connect waters from the mine site to nearby wells.

# Acid Mine Drainage, Metals Leaching, and Groundwater Contamination

Acid mine drainage and metals leaching, or AMD & ML (but usually referred to as simply AMD), is perhaps the most significant environmental problem facing mining operations. AMD is triggered by the oxidation of sulfide minerals when recently unearthed rock is exposed to air and water. This exposure causes sulfuric acid to leach from waste rock, tailings, pit walls and other areas where the rock is disturbed. It can also be generated from tailings dumps. The result is increased acidity in surface and groundwater, which then leaches metals from surrounding rock and further contaminates waters. Common heavy metals leached from AMD include iron, arsenic, copper, cadmium, lead, mercury, nickel, cobalt, chromium and manganese, among others.

Acid drainage is usually a self-perpetuating source of contamination that requires ongoing treatment before discharging to surface or groundwater. This treatment may be necessary for hundreds, or even thousands of years. Indeed, small mines built during the Roman Empire are still leaching acid and heavy metals today.

While modern treatment methods exist to mitigate many sources of AMD within a mine site (particularly lime treatment that neutralizes acidity), water treatment operations at large mines are extremely expensive. For example, at the Red Dog Mine in Alaska, water treatment costs are roughly $10 million per year (source[29]), and will remain in perpetuity. In many cases, treatment plant operating expenses are ultimately absorbed by governments, municipalities, and even citizen groups after a mining company declares bankruptcy and does not have a sufficient fund or bond in place to cover costs over the long term. This has frequently happened despite financial “assurances” put up by mining companies, which are generally inadequate (source[30]). The following resources are recommended for additional reading regarding AMD, financial bonding and government subsidies of mine cleanup and long term care. They provide many cases studies too numerous to mention in this report:

**This sample was taken directly from a pool of runoff water at a small abandoned mine in the Patagonia Mountains, a few miles away from the proposed Hermosa Mine. The water was later tested for acidity, and checked in at pH 2.5 – comparable to vinegar or lemon juice, and about five orders of magnitude more acidic than distilled water. The Hermosa mine would be many thousands of times larger than this mine and could generate proportional volumes of acidic water.** Photo by Pete Dronkers, Earthworks.

- Ground Truth Trekking AMD Page (source[31])
- Earthworks' detailed report about perpetual water treatment (source[32])

Accurately predicting acid drainage and engineering for mitigation at future mines is difficult and expensive and may not always be truly conclusive and effective. In a presentation (source[33]) by the Northern Alaska Environmental Center, case studies are provided from Canada showing that even after prediction efforts determined that AMD would not be problematic, mines still had unexpected AMD problems. A report by Kuipers and Associates entitled "Comparison of Predicted and Actual Water Quality at Hardrock Mines" offers additional insight into similar realities of AMD prediction (source[34]). Therefore, despite mine engineers and geochemists working to avoid AMD, there often remains a risk of unforeseen consequences. At many mine sites, it is well understood that AMD will be a characterizing factor of a mine's long term environmental performance, and we are aware of no cases in which AMD was predicted but never became a problem.

**Mitigation costs for acid mine drainage contamination from large, modern mines can cost hundreds of millions of dollars and is often paid for by taxpayers rather than mining companies.(source[i])**

The Patagonia Mountains have a long, well-documented history of water contamination caused primarily by AMD. Most notably, three sections of streams within the Patagonia Mountains (including Harshaw Creek) have been added to the state of Arizona's list of impaired waters, and do not meet the state's water quality standards. The pollutant loading is quantified in terms of Total Maximum Daily Loads, or TMDL's, for various contaminants. The TMDL listings were created under the jurisdiction and guidance of section 303(d) of the federal Clean Water Act. The Arizona Department of Environmental Quality asserts throughout reports for each TMDL listing that mining has had a major impact on water quality.

**Heavy rains in 2014 greatly increased the impact of acid drainage from abandoned mine sites in the Patagonia Mountains.**
Photo by Gooch Goodwin.

They state the following for each creek segment studied:

**Harshaw Creek:** ADEQ performed this investigation of upper Harshaw Creek in response to the stream being listed for violations of water quality standards on the 1996 and 1998 303[d] Lists. Flow in upper Harshaw Creek carries measurable quantities of copper and has excessively low pH [high acidity]. (source[35])

**Alum Gulch:** The segment was listed for impairments due to dissolved and total cadmium, copper, zinc, and acidity (pH)…Flow in upper Alum Gulch carries measurable quantities of cadmium, copper, and zinc and has excessively low pH [high acidity]…(source[36])

**3R Canyon:** This segment was listed for impairments due to beryllium, copper, zinc, and acidity [low pH]. As a result of monitoring for this study, it was found that the streams also were impaired for cadmium which was added to the 2002 303(d) list… (source[37])

As noted in a report entitled "tracking acid-mine drainage in Southeast Arizona using GIS and sediment delivery methods," prepared by the United States Geologic Survey (source[38]), acid drainage within creeks are largely the result of the ongoing erosion of mine tailings and waste material into waterways.

The TMDL reports for Upper Harshaw Creek also state:

> *Mining residues are a significant source of pollutants and consist of three major categories of material:*
>
> - *Waste rock removed to gain access to the ore. (This material may or may not have leachable metals.)*
> - *Low grade ore waste that has leachable metals in quantities that were uneconomical to extract at the time of mining.*
> - *Mill tailings which are the finely ground waste after separation from the economically useful minerals. (This material may or may not have leachable metals.)*
>
> *…The Endless Chain Mine is considered a significant source of all the constituents of concern [pollutants]. The Endless Chain Mine site includes a waste pile occupying a portion of the stream channel in the Endless Chain tributary.*
>
> *…The mining residues of the Morning Glory Mine occupy a portion of the channel at the headwaters of Harshaw Creek…experience suggests that this is a potential source due to the large volume of waste material and the prevalence of visible pyrite exposed at the surface.*
>
> *…Small mines may contribute to loading, but experience suggests that loading is usually proportional to the volume and exposed area of mining residues of similar composition.*

All of the above excerpts show that mining is a major source of pollution within surface waters of the creek segments listed on the 303(d) list. While the reports also acknowledge that natural erosion from rock outcropping and soils within the Patagonia Mountains likely contribute somewhat to diminished water quality, the problem is mostly mining related. This is evidenced by the fact that no creeks without mining disturbances have measured such extremely acidic water conditions, as have been documented within the mining-affected creeks. Additional local sampling by the Patagonia Area Resource Alliance also demonstrate that highly degraded waters can be taken directly from mine sites (originating from both tailings and waste runoff as well as underground workings), whereas those creeks without a history of mining contain cleaner, clear water with far more neutral pH levels.

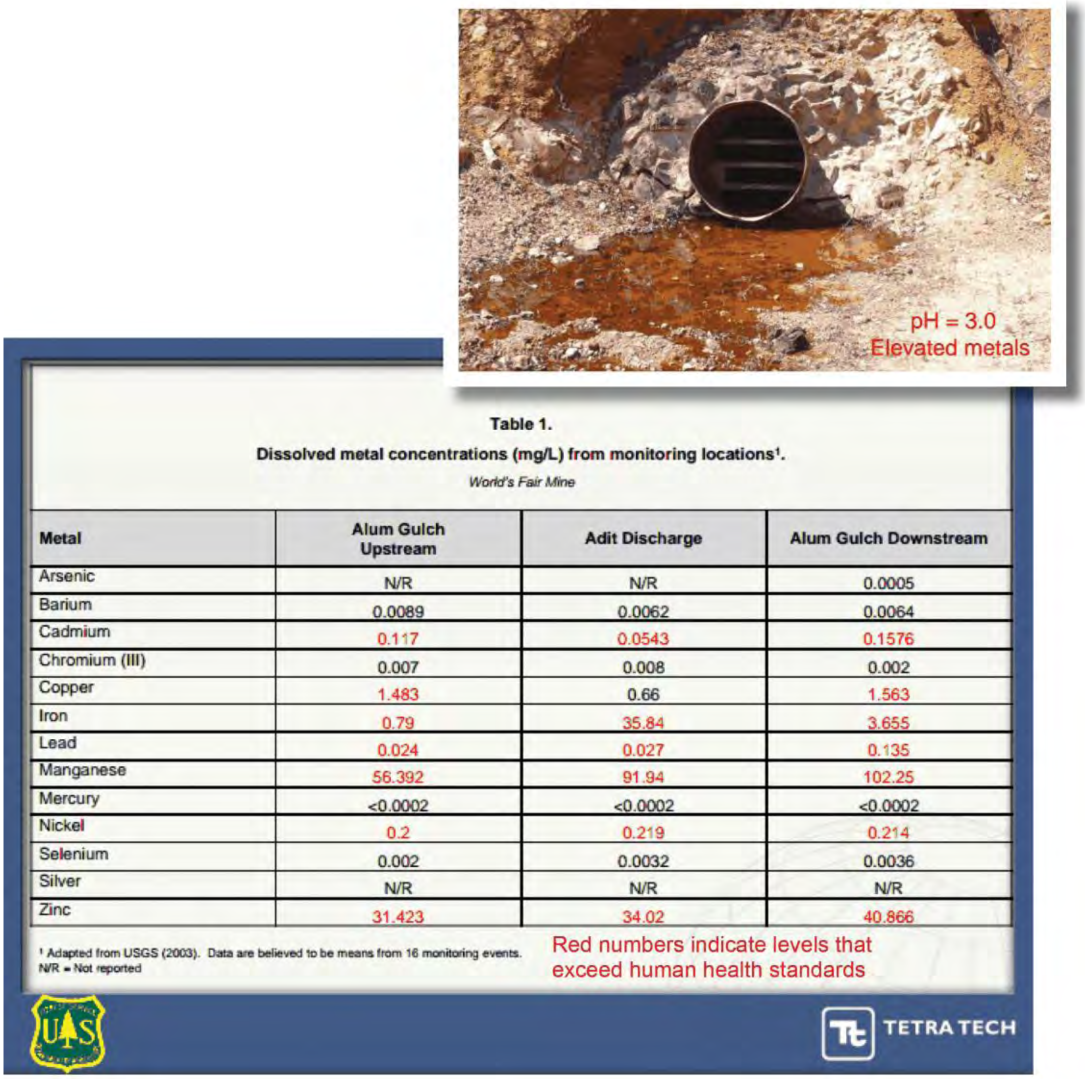


**Table 1.**

**Dissolved metal concentrations (mg/L) from monitoring locations[1].**

*World's Fair Mine*

| Metal | Alum Gulch Upstream | Adit Discharge | Alum Gulch Downstream |
|---|---|---|---|
| Arsenic | N/R | N/R | 0.0005 |
| Barium | 0.0089 | 0.0062 | 0.0064 |
| Cadmium | 0.117 | 0.0543 | 0.1576 |
| Chromium (III) | 0.007 | 0.008 | 0.002 |
| Copper | 1.483 | 0.66 | 1.563 |
| Iron | 0.79 | 35.84 | 3.655 |
| Lead | 0.024 | 0.027 | 0.135 |
| Manganese | 56.392 | 91.94 | 102.25 |
| Mercury | <0.0002 | <0.0002 | <0.0002 |
| Nickel | 0.2 | 0.219 | 0.214 |
| Selenium | 0.002 | 0.0032 | 0.0036 |
| Silver | N/R | N/R | N/R |
| Zinc | 31.423 | 34.02 | 40.866 |

[1] Adapted from USGS (2003). Data are believed to be means from 16 monitoring events.
N/R = Not reported

Red numbers indicate levels that exceed human health standards

**The World's Fair Mine, in Alum Gulch, Patagonia Mountains (source[g]). This mine was selected for remediation due to excessively high levels of acid mine drainage (roughly 4 orders of magnitude more acidic than water). The table shows heavy metal concentrations that exceed human health standards. The mine shaft was plugged with concrete to prevent contaminated water from leaking into the canyon, at a cost of $1.1 million which was paid for by taxpayers. Over about 70 years, this mine produced the same amount of ore that the Hermosa Mine would produce in a single day. Mitigation costs for acid mine drainage contamination from large, modern mines can cost hundreds of millions of dollars and is often paid for by taxpayers rather than mining companies (source[h]).**

The subject of the Arizona Department of Environmental Quality's TMDL analysis regards surface waters and not groundwater. This is partially due to the fact that the Clean Water Act, and section 303(d), only applies to surface waters. We are not aware of any studies specific to acid drainage within groundwater in the mountain range. However, the impacts documented from surface waters within the TMDL reports – waters which only flow at certain times of the year – are severe, yet the rest of the time much of this contaminated water simply percolates into the ground when there isn't enough precipitation to cause the creeks to flow.

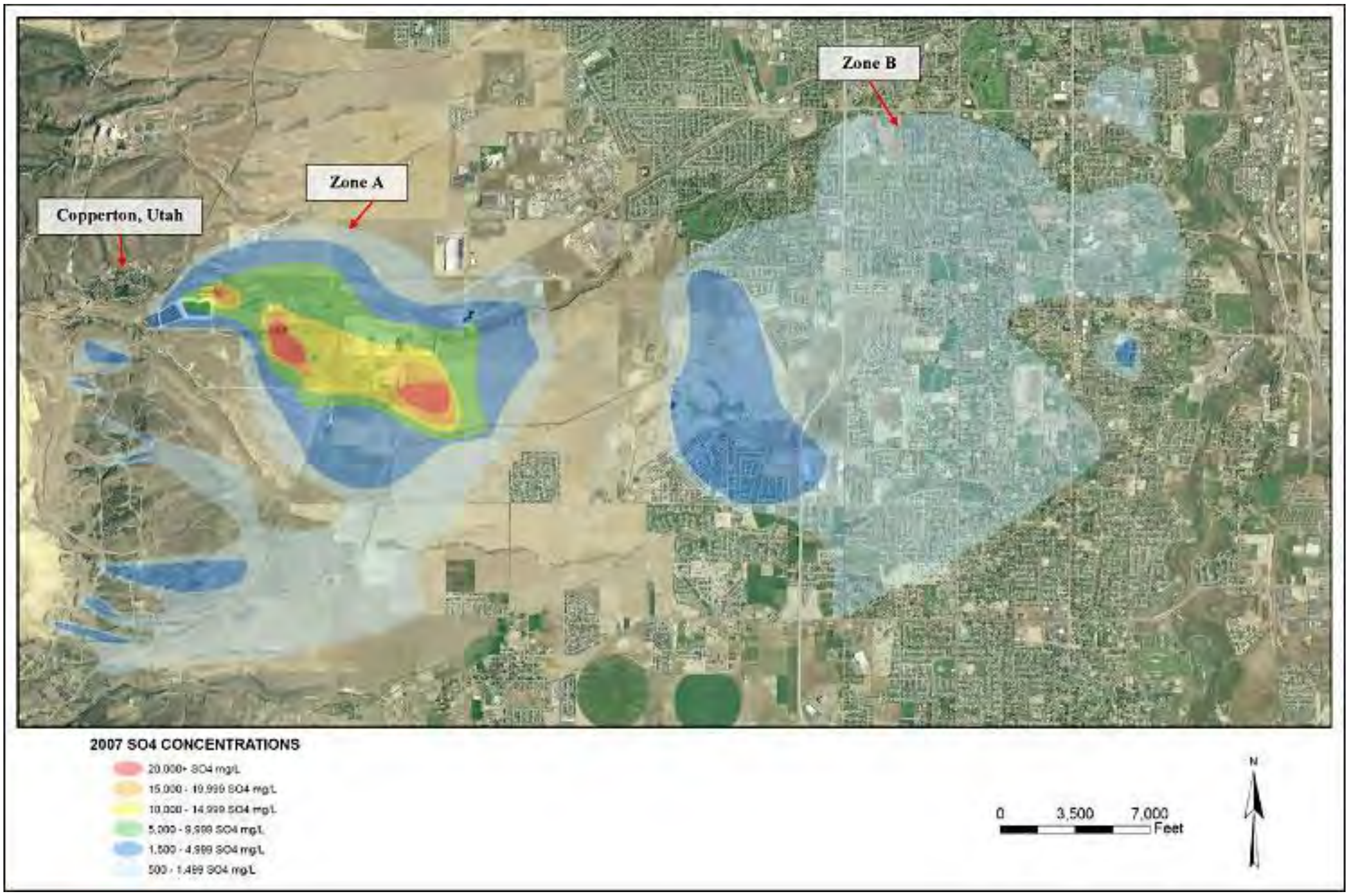
The groundwater contamination effects are exacerbated by the increased mobility of water and air (and therefore oxidation) within hundreds of thousands of feet of abandoned mine shafts and tunnels throughout the mountain range. Waters percolating into the ground near mine sites may already be highly acidic, but they may then enter a fragmented and perforated underground landscape, where the shafts and tunnels are generating AMD as well. Water not affected by mine waste on the surface also has the potential to percolate underground and intercept mine workings, where it then becomes subject to AMD generation. Therefore, AMD generation occurs not only on the surface, but also deep underground.

While the amount of pollutant loading may not be enough to cause regional groundwater contamination stretching as far as Patagonia today, it certainly has localized groundwater impacts. This is reinforced by the sample in the above photo, which was taken from a pool of water collected at the entrance to an underground mine and originated from the shafts behind it. Considering that the Hermosa Mine would be 1,679 times larger than the largest mine of the past, it is reasonable to believe that its contribution of acid drainage to the alluvial groundwater system in upper Harshaw Creek – and potentially deeper – could be extreme.

Specifically, below is a table showing the type of minerals present in the Patagonia Mining District, with minerals known to generate acid highlighted (source[39]). One of the most common acid generating minerals at the mine sites is pyrite (iron sulfide), also known as fool's gold. Wildcat Silver's pre-feasibility report (source[40], P. 50), states that "pyrite is by no means uncommon", based on drill results. Pyrite is also visible and common at many of the historic tailings dumps in the mining district. While some minerals known to act as AMD buffers are also present, history has shown us that the net effect in the Patagonia Mountains has been that of extreme acid generation. While more detailed analysis is needed to better characterize the AMD potential at the Hermosa Project, based on historic trends and the abundance of pyrite and other acid-generating minerals, we believe acid drainage is virtually assured, that perpetual water treatment and mitigation will be needed, and that some sources of AMD will not be reconcilable with technological solutions (see the end of this chapter for more about AMD mitigation technologies).

## Minerals present in the Patagonia Mining District. Minerals known to generate acid are highlighted.

Acanthite
Actinolite
Akaganeite
Anatase
Andradite
Anglesite
var: Argentiferous
Anglesite
Anorthite
var: Labradorite
'Apatite'
Arsenic
Arsenopyrite
Augite
Aurichalcite
Azurite
Baryte
'Bindheimite'
Bornite
Brookite
Calcite
Cerussite
var: Argentiferous
Cerussite
Chalcanthite
Chalcocite
Chalcopyrite
Chalcosiderite
Chamosite
Chenevixite
'Chert'
Chrysocolla
Copper
Covellite
Cryptomelane
Cuprite
Digenite
Diopside
Dumortierite
Epidote
Epsomite
Ferberite
Ferrimolybdite
Galena
var: Argentiferous Galena
'Garnet'
Gedrite
Goethite
Gold
Grossular
Gypsum
Hedenbergite
Hematite
var: Specularite
Hemimorphite
'Hornblende'
Hydrozincite
Ilmenite
Jarosite
Johannsenite
Kaolinite
'K Feldspar
var: Adularia'
'Limonite'
Linarite
Luetheite (TL)
Magnetite
var: Lodestone
Malachite
Manganite
Marcasite
Melanterite
Mesolite
Microcline
Molybdenite
'Molybdenite-2H'
Muscovite
var: Sericite
Orthoclase
Palygorskite
Phlogopite
Powellite
'Psilomelane'
Pyrite
var: Cupriferous Pyrite
Pyrolusite
Pyromorphite
Pyrrhotite
Quartz
var: Amethyst
Rhodochrosite
Rosasite
Rutile
Scheelite
Schorl
Siderite
Silver
Smithsonite
Sphalerite
Stephanite
'Stilbite'
Sulphur
Talc
Tennantite
Tetrahedrite
Tremolite
Vanadinite
Vesuvianite
'Wad'
Wollastonite
Wulfenite
'Zinnwaldite'
Zircon



**Sulfate plumes from large mines can impact the water supply of local communities, as has this one at the Bingham Canyon Mine in Utah where some sulfate levels are over 80 times the maximum standard set by the US Environmental Protection Agency. Sulfates are considered to be a precursor to heavy metal contamination (source[i]).**

In addition to heavy meals leaching and AMD, sulfate plumes caused by large mines are well documented to have significant impacts to local communities. One of the most well-known cases of this is the Bingham Canyon Mine near Salt Lake City, Utah. Sulfate from numerous sources has caused a groundwater plume to reach nearby farms, ranches, and homes, rendering many wells undrinkable. The plume remains despite extremely expensive and ongoing mitigation efforts, including pumping out groundwater, treating it, and re-injecting it into the aquifer. In the image below, the lightest shades of contamination represent between two and six times the maximum levels of sulfate considered safe by the US Environmental Protection Agency (EPA). The red shades represent at least 80 times the EPA maximum standard.

In Arizona, several large mines have created sulfate plumes as well. In Green Valley, 25 miles from Patagonia, the Sierrita Mine sulfate plume has angered nearby residents. According to a 2005 article in the Green Valley News (source[41]), two community wells had to be shut down when levels approached 1000 milligrams per liter – four times the current EPA standard. According to the article, sulfate plumes are typically an indication that metals leaching will come later. "It is common knowledge in mining that metals follow sulfates," said Allan MacDonald, a retired environmental consultant. "The sulfates are a harbinger of things to come."

In Bisbee, Arizona, the Copper Queen Mine continues to have sulfate plume issues despite it being closed since 1975. According to a 2008 Sierra Vista article (source[42]):

> *The plume remains around 3 ½ miles long, around two miles wide and runs 200 to 300 feet deep…A limit of 250 milligrams per liter is the standard maximum amount set by the Environmental Protection Agency. Some sites have sulfate readings between 800 and 1,000 milligrams per liter. Others near the old evaporation pond run between 1,320 to 2,210 milligrams per liter… For some time now, people who usually use private wells that have already been discovered to have a high quantity of sulfate receive bottled drinking provided by the mining company.*

These are only three cases of many within the western states regarding sulfate plumes. While it should be noted that these cases are located directly on top of larger, porous alluvial systems through which the plumes travel more easily, it should be kept in mind that while Hermosa is more constrained within the mountains, it is also cited above a known alluvial, porous hydrologic system through which sulfate could travel – the Harshaw Creek drainage.

More research would add more to this list, and lend insight into the metals leaching issues associated or expected within some of these operating and closed mine sites. While sulfate itself is not toxic at the encountered levels at these sites, case studies show that the groundwater can become undrinkable, as it is known to cause diarrhea and stomach pain. With that in mind, it is the heavy metals and increased acidity that either accompany or follow the initial sulfate plume that have more serious implications for water treatment and human health. Those following the Hermosa Project should be aware that while definitive analysis is impossible at this point, widespread groundwater contamination – reaching as far as town – is very possible, and would be just one of many such cases in Arizona.

## Arsenic and Nitrate Contamination

Arsenic contamination, which can occur separately from acid drainage but is also exacerbated by it (arsenic can be released in varying pH environments), can be a major and very long lasting problem at mines with arsenopyrite – a mineral known to exist within the Patagonia Mountains (source[43]). Arsenopyrite can produce acid and leach arsenic – a poisonous metalloid – into groundwater. The national Institute of Health recently found that even low doses of arsenic can cause lung cancer in mice (source[44]).

According to a study from the National Center for Biotechnology (source[45]), "When humans are implicated in causing or exacerbating arsenic pollution, the cause can almost always be traced to mining or mining-related activities." Though arsenic is naturally present in some groundwater, the mobilization of it into the environment is usually mining-related.

Nitrate groundwater plumes can also degrade groundwater at open pit mines (source[46]). Nitrate contamination is usually caused by explosives (ammonia contamination can also be associated with blasting agents) or by oxidation of cyanide complexes following leaching in mills or heap leach piles. This issue is not generally considered in federal Environmental Impact Statements; therefore, the permitting system does not take into account nitrate contamination mitigation. According to the Idaho Department of Environmental Quality (source[47]), infants, the elderly, and sick people should not drink water higher than 10 milligrams per liter nitrate (some consider this the maximum contaminant level for all humans), and livestock should avoid water higher than 100 milligrams per liter.

Fuel and chemical spills on roadways and within the mill can also contribute to groundwater degradation, as can some forms of dust suppression agents (source[48]). Finally, as we will see later in the report, catastrophic failures such as tailings impoundment dam failures and solution pond breaches can be extraordinarily destructive and have severe impacts that last generations.

## Acid drainage and modern mining

Modern, large scale mining in the United States certainly benefits from a far more advanced scientific understanding of the causes of acid drainage and metals leaching (as well as other forms of water contamination) than was available when the Patagonia area mines were developed. Current AMD mitigation and remediation techniques reflect this, and modern environmental regulations and statutes help to put this knowledge to good use to achieve protections that were not available decades ago.

While this increased geochemical knowledge can help with some aspects of how a mine is developed, they cannot solve major remaining issues. For example, decades ago, tailings materials were simply dumped in a creek bed, whereas today buffering agents may be added to reduce the risk of AMD, and they are placed in engineered impoundments with liners that help to prevent the flow of acid into the groundwater. Water from the surface of the impoundment and the mill effluent is treated if it is to be discharged, and most other sources of discharges must comply with the Clean Water Act.

However, while these measures are essential, they do not stop the need for perpetual water treatment at mines with unfavorable geochemistry. They do not prevent acid drainage from the massive slopes of an open pit from contaminating groundwater under the pit, or prevent runoff from waste rock from compromising water quality underneath them. Modern technologies cannot solve the problems associated with a cone of depression and perpetual pit lake evaporative loss, nor have they enabled mines to operate using pollution-free sources of energy.

The mining industry commonly frames modern technology as the preventive cure for current and future pollution, yet in most cases in which AMD or other pollution is expected, technologically advanced systems for mine engineering and water treatment tend to simply defer pollution to a later date rather than solve the intrinsic problems. In many cases in which a mining operation is expecting water treatment in perpetuity, the long term cost of treatment and mitigation can exceed the economic value of the minerals being extracted, rendering the entire operation fiscally insolvent from a long term perspective and pushing environmental and financial liabilities onto future generations.

Beyond this, environmental problems are commonly realized during the life of the mine, as the numerous references contained within this report demonstrate. In preparing it, we have found little evidence to suggest that complete and successful reclamation of the Hermosa Mine – as currently planned – can occur without long-term expense and liability, despite mitigation technologies and techniques that are far superior than those of decades past. As we will express in this report's conclusion, those solutions may require a vastly different approach to mining prompted by thorough regulatory reform.

Finally, reclamation and water treatment bonding is worth discussing in this context as well. Mining companies operating in the US are required to post bonds for reclamation of the site after mining is concluded. Part of the bonding package includes money to handle perpetual water treatment where it is predicted. However, because this money is limited to just a small fraction of the initial capital expenditures of the mine, and water treatment in perpetuity is an ongoing expense, these funds rely on interest gained from investments over time within a complex web of accounts in both the public and private domains. The performance of these funds is simply a function of the national – and even international – economic condition. When the economy grows, these funds – if capitalized enough in the first place – can in theory gather enough interest to maintain the water treatment costs. But they often don't. Even many mines built in recent decades – a time when the US economy expanded rapidly, have still defaulted on their water treatment and other liabilities and have been bailed out by taxpayers after the original mining company filed for bankruptcy (source[49])

Moving ahead from today, we see a global and national economy struggling to maintain the growth rates of the last several decades. In the US, national and private debt continue to skyrocket, the purchasing power of the middle class continues to weaken, and growth rates are a fraction of their historic highs. Oil prices that were once a minor concern are now at the bottom lines of extractive industries – particularly mining – having risen three fold in just over a decade. Meanwhile, ore grades at mines continue to decline, additionally exacerbating the financial difficulties of the industry and casting doubt on its long-term ability to remain fiscally healthy enough to continue funding water treatment plants. There is legitimate reason to believe that the US and global economy will not continue growing at rates similar to those of the past (this is already the case), and that a steady-state economy (one that does not grow), or even negative economic growth may occur long before the liabilities of legacy mines fade away. Therefore, we believe it is critical to look at water treatment liabilities through the lens of the broader economic condition and its long-term trajectory rather than simply a bond amount posted at the time of mine construction that may appear to be a large sum of money.

# Energy Consumption and Carbon Emissions

Hardrock mines use incredible amounts of energy and are major contributors to climate change. Although an exact calculation for the Hermosa Mine is not possible until a Plan of Operations is completed, we can compare the project to other proposed and operating open pit mines for both electricity and diesel fuel consumption. The vast majority of electricity in open pit mines is used in the mill, although in terms of total energy used, as much, if not more, is used in haul trucks – the largest of which can consume up to 65 gallons of diesel fuel per hour.

Below is a chart showing four operating or proposed open pit hardrock mines

| Mine | Electricity Consumption | Mill Throughput | Kilowatt-hours per ton of mill throughput |
|---|---|---|---|
| Donlin Gold | 153 Megawatts | 59,000 tons/day | 62 kwh |
| Fort Knox | 35 Megawatts | 40,000 tons/day | 21 kwh |
| Livengood | 75 Megawatts | 100,000 tons/day | 18 kwh |
| Pebble | 378 Megawatts | 200,000 tons/day | 45 kwh |

Note: Unlike the Hermosa Mine, two of these mines (Fort Knox and Livengood) utilize or plan to utilize heap leach extraction, which requires far less electricity than crush, grind, and flotation circuits which would be utilized at Hermosa. Further analysis could increase the size and parameters of this statistical pool to better reflect conditions at Hermosa, and yield a more refined estimate.

Although mines vary in electricity use per ton of mill throughput based on factors such as ore grades, transmission distances, rock hardness, equipment utilizing electricity rather than diesel (such as electric shovels), and type of extraction and concentrating circuits employed (see note above), averaging the above mines together creates an average use of about 36.5 kilowatt-hours per ton. This is consistent with inquiries for this report to mining industry experts who have suggested that consumption for non-heap leach, open pit hardrock mines (like Hermosa), average between 30 and 50 kilowatt-hours per ton when using a large statistical sampling pool.

Applied to Hermosa, this average would amount to 500 Megawatt-hours per day, or 20.8 megawatts of ongoing current to supply the mine with electricity around the clock. According to the US Energy Information Administration, the average US household consumes 903 kilowatt-hours per month (source[50]), which equals an average current of 1.25 kilowatts. Therefore, the Hermosa Mine may consume as much electricity as over 16,640 single family homes, or 35,681 Arizonans (source[51]).

The electricity would likely come from the Sulphur Springs Valley Electric Cooperative – an electric utility that distributes coal-fired electricity – or from an intertie to another grid within the southwest that likely burns primarily coal or natural gas. According to the Sulphur Springs

Valley Electric Cooperative's annual report for 2012 (source[52]), average current provided by the utility was 97 megawatts. Therefore, the Hermosa mine would require about 1/5 of the power currently generated by the regional electric grid, which services some 50,811 meters.

According to the US Energy Information Administration (source[53]), coal fired power plants produce on average about 2.1 pounds of carbon dioxide per kilowatt-hour of generation. Therefore, the Hermosa mine – if using coal-fired electricity – would produce about 383 million pounds of carbon dioxide emissions per year. This is equivalent to the pollution produced by over 50,000 average cars in the US per year (source[54]).

Coal fired electricity also consumes large amounts of freshwater for power plant cooling. According to a factsheet from the Arizona Water Institute (source[55]), coal-fired generation consumes 510 gallons of water per megawatt-hour of electricity. At 500 Megawatt hours per day, the Hermosa Mine would therefore consume an additional 255,000 gallons per day, or 93 million gallons (285 acre feet) of water, per year.

## Diesel Fuel

Although open pit mines require increasing amounts of diesel fuel per unit of excavated material as the mine grows deeper, we can generally estimate diesel fuel needs based on comparisons to proposed and operating mines elsewhere. Some mines derive all or a portion of needed electricity from diesel fuel generation, but because the Hermosa Mine is likely to tie into a regional power grid, it would probably use diesel primarily for haul trucks, loaders, bulldozers, drill rigs, support vehicles, and other miscellaneous uses, and not for electricity generation.

Mine-specific diesel consumption data is difficult to obtain, and diesel consumption varies under many factors, but we can compare Hermosa with an open pit mine proposal (with a similar stripping ratio) for which data is available: the Donlin Gold Mine. According to the Donlin Gold Plan of Operations (source[56]), the open pit mine – which, like Hermosa, would not use diesel fuel for electric generation – would use 40 million gallons of diesel per year to sustain a 59,000 ton daily throughput, or 21.53 million tons per year. This equals 1.86 gallons of fuel per ton of ore milled. Applied to Hermosa, this would result in annual diesel fuel consumption of roughly 9.3 million gallons.

**Predicted greenhouse gas emissions: 591 million pounds per year – about the same as 71,000 average US automobiles.**

Diesel fuel produces 22.38 pounds of carbon dioxide emissions per gallon when burned (source[57]). Therefore, the Hermosa mine would produce about 208 million pounds of carbon dioxide emissions from diesel fuel. This, combined with the emissions associated with coal fired electricity generation, amounts to 591 million pounds of greenhouse gas emissions each year – about the same as 71,000 average US automobiles.

For additional reading, below are some sector-wide mining industry studies that calculate total energy and diesel fuel use.

- Estimates of Electricity Requirements for the Recovery of Mineral Commodities with examples applied to Sub-Saharan Africa[58]

- Mining Industry Energy Bandwidth Study, US Department of Energy[59]
- Benchmarking the energy consumption of Canadian Open Pit Mines, Natural Resources Canada[60]
- Analysis of diesel use for mine haul and transportation operations, Australian Government[61]

# Other Impacts

## Catastrophic Failures

Failure of tailings dams are the most common type of environmental catastrophe at mine sites. Tailings impoundment failures can be caused by engineering design flaws, floods, mismanagement of the mine resulting in overloaded impoundments, and earthquakes. Flash floods are perhaps the most probable at the Hermosa Mine, given the nature of monsoonal rains during which a single event can produce a significant portion of the entire year's expected rainfall.

In August 2014 in British Columbia, a major tailings dam breach at the Mt. Polley Mine near the town of Likely flooded Hazeltine Creek with 14.5 million cubic yards of tailings materials, including 4.5 million cubic meters of tailings sediment with thousands of tons of heavy metals contained within it. Part of the release entered Polley Lake while the rest traveled several miles down Hazeltine Creek, uprooting thousands of trees and scouring the river from its original four foot width to over 150 feet wide. The release then entered Quesnel Lake, which flows into the Fraser River, an important salmon fishery. The impacts to the regional fisheries ecosystem are likely to be extreme and very long-lasting.

Also in August, a catastrophic failure of a holding pond containing sulfuric acid and dissolved copper released approximately 10 million gallons of the highly acidic and toxic leach solution directly into the Bacanuchi River in northern Sonora state, Mexico. This spill continued on to contaminate the Sonora River, forcing thousands to avoid drinking surface or groundwater. As a result, nearly 90 schools located along the river have closed until water quality is determined to be safe (source[62]). The same week, a mine in Durango state, Mexico, experienced a smaller spill in which a cyanide leach solution escaped from a holding pond, leading to contamination (source[63]).

**In 2014, a tailings dam at the Mt. Polley Mine in British Columbia completely failed, dumping over 14.5 million cubic yards of tailings materials laden with heavy metals into Polley Lake, down several miles of Hazeltine Creek, and into Quesnel Lake – a tributary of the salmon-rich Fraser River (source[d]).** Photo by Jonathan Hayward, The Canadian press.

**The Mt. Polley disaster is one of many well-documented mine tailings breaches worldwide. A listing of dozens of major tailings dam failures worldwide can be found at the wise-uranium.org website (source[e]).**

## Air Emissions

**Residents of Arizpe, Sonora state, Mexico, receive bottled water after an August, 2014 accident at the Buenavista Mine near Cananea resulted in 10 million gallons of sulfuric acid laden with extreme levels of dissolved copper to be released into the Banacuchi River – a tributary of the Sonora River. The contamination spread 150 miles down the river system. (source[c])**

In addition to carbon dioxide emissions, hardrock mines create many other types of hazardous air emissions. Diesel exhaust emits nitrogen oxide and sulfur dioxide – compounds known to cause acid rain – though in lesser quantities than previous years based on ultra-low sulfur diesel standards and cleaner burning engines. Mercury air emissions have been very problematic at some hard rock mines as well, but more research is needed to determine if this is expected at Hermosa. Mercury is a highly toxic heavy metal that accumulates in the food chain and is extremely dangerous to human health, especially for pregnant women, infants, and the elderly.

Fugitive dust ("fugitive" means not from point sources) is a common problem at most open pit mine sites and can be harmful to health and air quality. Fugitive dust can contain particulate matter with particle size diameters from under 2.5 microns to over 10 microns, with the former being more hazardous to respiratory health. Although some mines have fugitive dust control and suppression programs that greatly reduce dust from roadways and in other high use areas, many mines still emit plumes of dust that can be visible from many miles away, making it a regional air quality and visibility issue. Blasting, pit walls, and the dumping of waste rock are all sources of dust for which control and suppression measures are not usually employed.

## Light and Noise

Virtually all large hard rock mines today operate around the clock, as shutting down operations on a daily or other periodic basis is not generally feasible. Lighting is installed on roadways, around buildings, and elsewhere and can be seen from many miles away. Some mines are proposing to use specialized LED lighting systems that avoid some of the reflection into the sky, though if the ground is lit, it will be visible elsewhere. Light pollution is of special concern to the Mt. Whipple Observatory, with regard to the proposed Rosemont Mine, which is situated less than five miles from the base of the mountain. The Hermosa project is about 15 linear miles from the Observatory.

Noise pollution will also be a noticeable impact. Blasting, trucking and milling are especially noticeable when downwind or during times of still winds, when sound can travel miles. Finally, blasting poses threats to the structural integrity of homes and buildings near the mine site, including several that are just half a mile from the edge of the proposed pit.

At right: around-the-clock mining operations compromise night skies in largely undeveloped regions. (source[64])

## Tourism and Business

A mine with a 3.5 square mile footprint is likely to impact tourism that many businesses within Patagonia have come to rely upon. This includes hiking, birding, hunting, off road vehicles, and other recreational pursuits. Permanent widening of narrow and rough dirt roads will diminish all of these existing recreational activities near the mine site.

**Around-the-clock mining operations compromise night skies in largely undeveloped regions (source[b]).**

## Cumulative Impacts

Cumulative impacts should be considered as well. Construction of a mine increases global demand for commodities such as steel, aluminum, and copper, thereby adding to the global energy and water requirements of industrial activity, and also increasing the worldwide pollution tally. In addition, commodities sourced from other, less regulated nations through the supply chain – though this can be difficult to track – may have substantially higher environmental impacts elsewhere. In comprehensive environmental impact analyses of mines, the cumulative – often global – impacts should be considered, not simply impacts of the mine in question.

## Wildlife and Livestock

Due to groundwater depletion and it’s likely impact on surface springs, wildlife and livestock would be at increased risk if the mine is built. Birds, including the Mexican Spotted Owl – a species currently considered “threatened” under the Endangered Species Act – is particularly at risk. The Patagonia Mountains are considered "critical habitat" for the owl, and the range contains three known nesting and roosting areas  all of which are in drainages adjacent to the mine site, with two being directly downstream from the site. Jaguar has also been documented in the Patagonia Mountains as well; the species is listed as “endangered” under the Endangered Species Act. The Patagonia Mountains are believed to be the corridor through which the jaguar travel to reach the Santa Rita Mountains, where they have been documented and photographed recently.

Mearns Quail is a popular bird for hunters in the Patagonia Mountains; it's habitat would be impacted if the springs on which they depend run dry from groundwater depletion, impacting several business that specialize in hunting the species in the area.

Livestock is also at risk, as some ranchers near the mine site rely on surface water and springs to water their cattle. Groundwater depletion could also require agricultural wells to be drilled deeper, increasing costs for ranchers already facing challenges due to existing drought.

# Concluding Note:

We believe the most viable method of mine development is one that does not present threats that must be dealt with for hundreds, if not thousands of years, at significant financial cost and with significant environmental consequence in the event of a failure of such maintenance. The seemingly inescapable realities of acid drainage and water consumption impacts pose too great a risk for the authors of this report, and we therefore oppose the Hermosa Mine as currently proposed. However, we also understand that local communities may still decide that the tradeoffs are acceptable. As we stated earlier, our goal has not been to declare an anti-mining position, but rather to provide the most accurate and pertinent facts from which the debate can benefit. We simply encourage readers to think critically about the impacts – both short term and long term – to all people within the region. We believe this issue is not about idealism, but about tradeoffs now and impacts to future generations.

We also believe that under a sensible regulatory environment, mines could conceivably be built in ways that largely eliminate these risks. For example, a prohibition of open pit mines where acid generation is expected, combined with requirements for backfilling underground workings and stabilizing the pH of all waste left on the surface, could potentially yield a design that does not have major perpetual liabilities. In places with water scarcity issues, laws could mandate a cap on mine water consumption that is consistent with the studies and recommendations of third-party hydrologists. New recycling and milling techniques could be innovated as a result. Wind and solar energy combined with hybrid machinery could help cut down on carbon emissions.

Could such solutions be possible for the Hermosa Mine? Much more study would be needed to determine that, but we believe we owe it to ourselves and to future generations to consider such requirements. If they cannot be met, perhaps a given mine should not be built. If a particular mining company cannot walk away from a mine without perpetual care, and without perpetual hydrologic impacts, perhaps we should treat the situation the same as we would in our own homes. How many of us would allow a contractor to remodel our kitchen knowing that he or she will leave the job with a leaking pipe spilling into the subfloor, yet stick us with the full bill anyway, not to mention future bills when the rotten floor needs to be replaced?

Fortunately, there is legal recourse for bad home remodel jobs, but within the hardrock mining industry – still today governed by the General Mining Act of 1872 without a single amendment – the industry is under no such mandate to act responsibly, and to finish what it started before it becomes a problem. We believe that starting with sweeping regulatory reform in the mining sector may be the best way to help cut down on conflicts like these. Such reform could also ensure a more democratic process with mine development, and put the ultimate decisions in the hands of the local communities rather than government.

We hope that this report has been helpful, and that those in support of the mine are aware of what life in the area may be like in 5, 10, 25, 50, and 100 years down the road if the mine is built as it is planned now.

The author and the Patagonia Area Resource Alliance encourage those with specific questions, concerns, thoughts, or corrections regarding this report to contact us. We strive for accuracy and ongoing dialog from all stakeholders.

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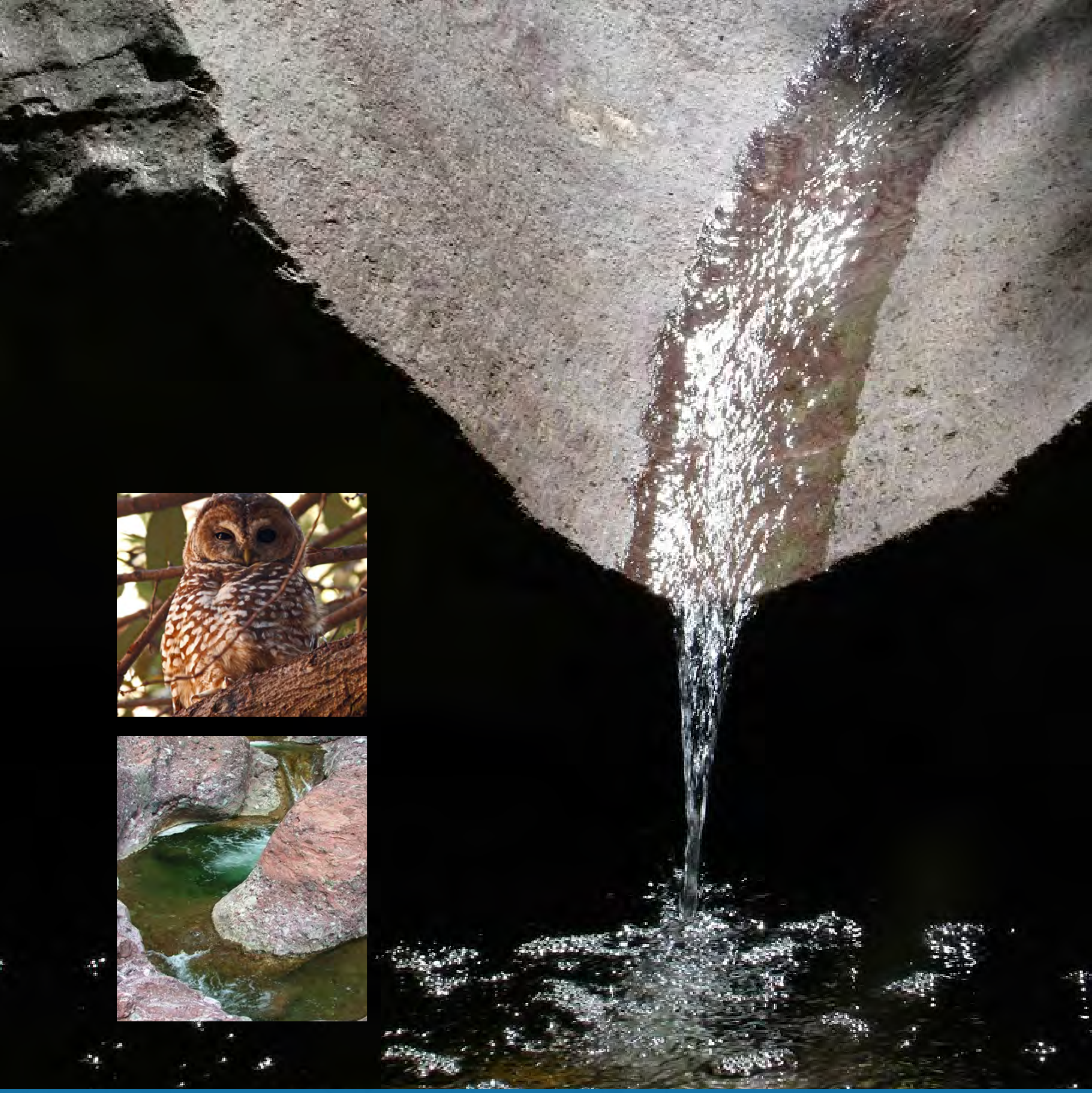

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