How to Turn Fresh Water into Toxic Waste: The Resolution Copper Project as a Case Study

Steven H. Emerman
Presentation in San Tan Valley, Arizona
January 15, 2026

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Today's Presenter

The presenter's 60th birthday party at Standing Rock Indian Reservation

Prof. Steven H. Emerman

- M.A., Geophysics, Princeton University
- Ph.D., Geophysics, Cornell University
- Professor of Geology for 31 years
- Over 70 peer-reviewed publications in mining, hydrology and geophysics
- Co-Author of Safety First: Guidelines for Responsible Mine Tailings Management
- Owner of Malach Consulting, specializing in environmental impacts of mining

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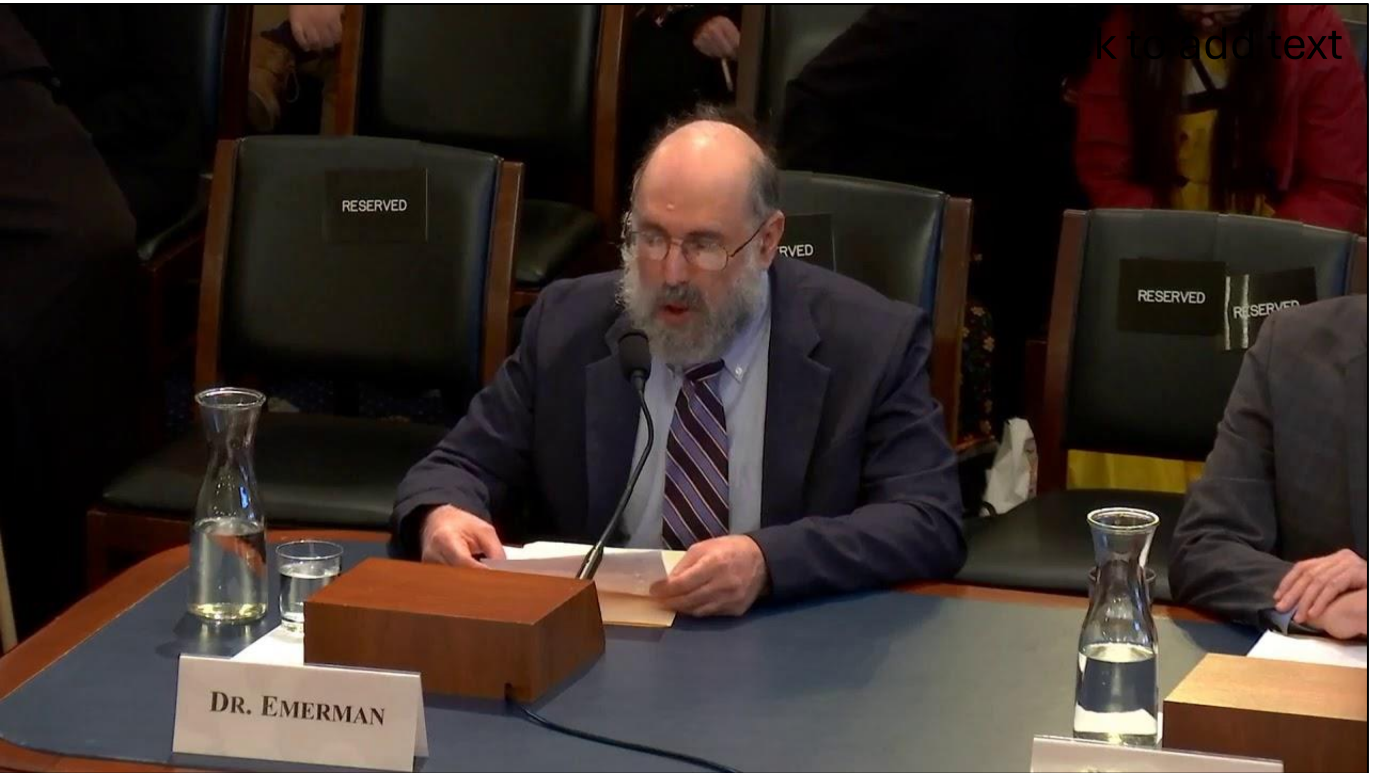
Prof. Emerman has evaluated proposed and existing mining projects in North America, South America, Europe, Africa, Asia, and Oceania. He has testified on mining issues before the US House Subcommittee on Indigenous Peoples of the United States, the European Parliament, the United Nations Permanent Forum on Indigenous Issues, and the United Nations Environment Assembly.



Prof. Emerman is the former Chair of the Body of Knowledge Subcommittee of the U.S. Society on Dams.

Prof. Emerman testifying before the U.S. Congress on March 12, 2020.

The Chemical Reaction of Industrial Mining

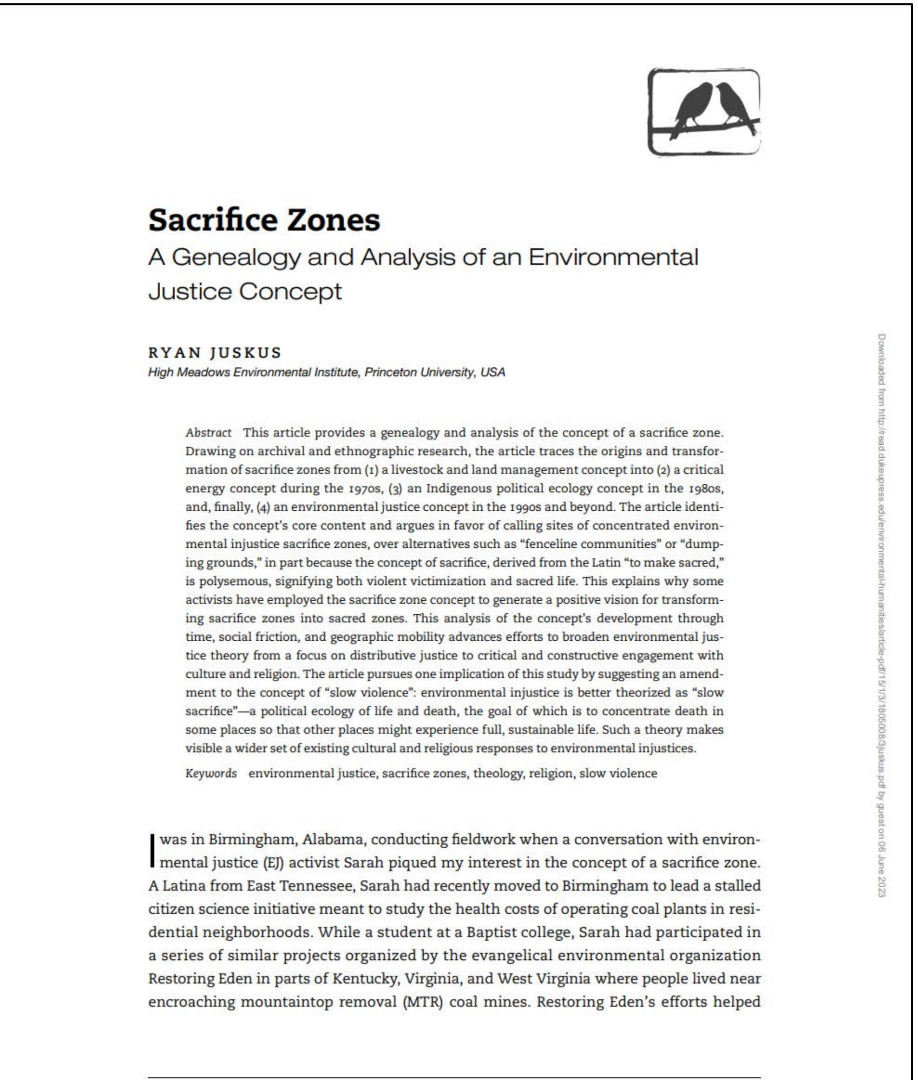
Fresh Water + Landscape →
Toxic Waste + Degraded Landscape + Commodity

Toxic waste is the driver for the consumption of fresh water, so these two components of the chemical reaction must be discussed together.

Is the Commodity worth the Price?

- Who benefits from the commodity?
- Who suffers the damages from the production of the commodity?
- Who bears the risks from the production of the commodity?
- Is it the same people who benefit and who suffer the damages and bear the risks?
- Who decides whether the commodity is worth the price?

The Concept of the Sacrifice Zone



Sacrifice Zones

A Genealogy and Analysis of an Environmental Justice Concept

RYAN JUSKUS
High Meadows Environmental Institute, Princeton University, USA

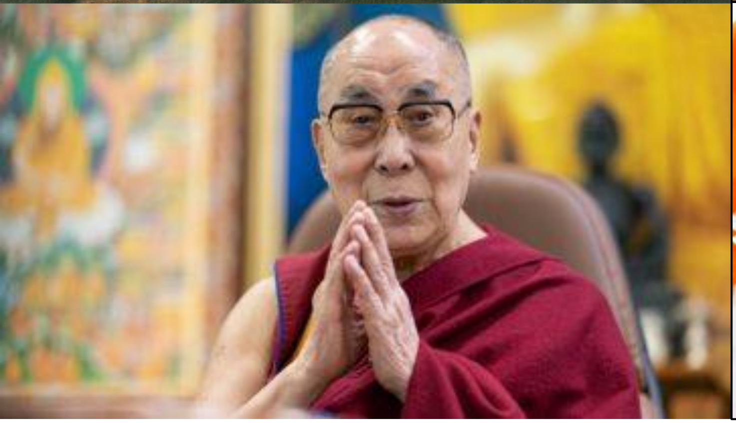
Abstract This article provides a genealogy and analysis of the concept of a sacrifice zone. Drawing on archival and ethnographic research, the article traces the origins and transformation of sacrifice zones from (1) a livestock and land management concept into (2) a critical energy concept during the 1970s, (3) an Indigenous political ecology concept in the 1980s, and, finally, (4) an environmental justice concept in the 1990s and beyond. The article identifies the concept's core content and argues in favor of calling sites of concentrated environmental injustice sacrifice zones, over alternatives such as "fenceline communities" or "dumping grounds," in part because the concept of sacrifice, derived from the Latin "to make sacred," is polysemous, signifying both violent victimization and sacred life. This explains why some activists have employed the sacrifice zone concept to generate a positive vision for transforming sacrifice zones into sacred zones. This analysis of the concept's development through time, social friction, and geographic mobility advances efforts to broaden environmental justice theory from a focus on distributive justice to critical and constructive engagement with culture and religion. The article pursues one implication of this study by suggesting an amendment to the concept of "slow violence": environmental injustice is better theorized as "slow sacrifice"—a political ecology of life and death, the goal of which is to concentrate death in some places so that other places might experience full, sustainable life. Such a theory makes visible a wider set of existing cultural and religious responses to environmental injustices.

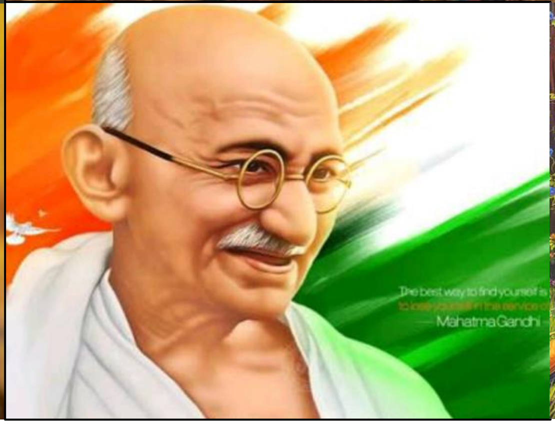
Keywords environmental justice, sacrifice zones, theology, religion, slow violence

I was in Birmingham, Alabama, conducting fieldwork when a conversation with environmental justice (EJ) activist Sarah piqued my interest in the concept of a sacrifice zone. A Latina from East Tennessee, Sarah had recently moved to Birmingham to lead a stalled citizen science initiative meant to study the health costs of operating coal plants in residential neighborhoods. While a student at a Baptist college, Sarah had participated in a series of similar projects organized by the evangelical environmental organization Restoring Eden in parts of Kentucky, Virginia, and West Virginia where people lived near encroaching mountaintop removal (MTR) coal mines. Restoring Eden's efforts helped

"[The sacrifice zone] is fundamentally a geographical concept about the production of space: environmental harms are concentrated in some places in order to protect the environmental health and sustainability of other places. Geographies of environmental sacrifice have been the necessary corollary of geographies of environmental abundance. The latter depend on and are constituted by the former … In short, the sacrifice zone concept signals a 'we' who are singled out by some criteria as an acceptable sacrifice and 'they' who use the powers of state, market, and mindset to do both the rationalizing and the sacrificing."

No One and No Place has an Obligation to Serve as a Sacrifice Zone



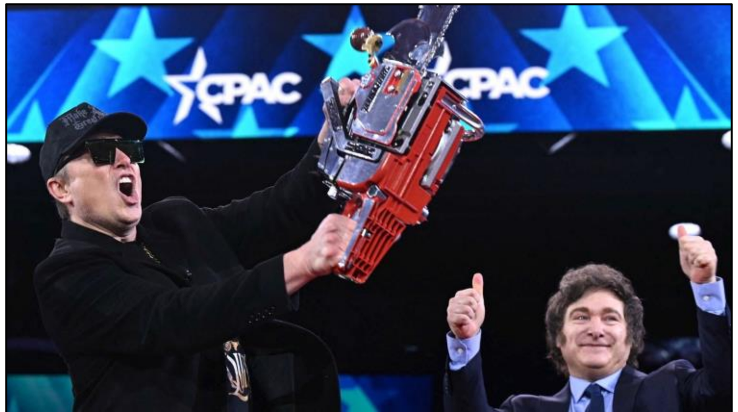


Is there any world religion that offers any justification for the concept of a sacrifice zone?

How Far have We Fallen that is Now Acceptable to Demand that Someone Else Serve as a Sacrifice Zone?

"As for me, I accept the degradation of part of our environment for the betterment of the whole to get sufficient energy production to keep our society functioning, and bring health, electricity and better living conditions to the rest of the world ... So, although to some it may seem callous, I accept the loss of the pristine deserts in South America to get the lithium we need ... But it will be lost and probably has to be lost unless we find another way to build Tesla's (and other) batteries."

-- Past President, Geological Society of America



How Far have We Fallen that is Now Acceptable to Demand that Someone Else Serve as a Sacrifice Zone?

From: Harry Cabrita <harrycabrita@gmail.com>
Sent: Tuesday, November 14, 2023 11:02:31 AM
To: Mayor's Office <mayor@cbrm.ns.ca>; Gordon D. MacDonald <gdmacdonald@cbrm.ns.ca>; Earlene D. MacMullin <edmacmullin@cbrm.ns.ca>; Cyril A. MacDonald <camacdonald@cbrm.ns.ca>; Steve D. Gillespie <sdgillespie@cbrm.ns.ca>; Eldon MacDonald <emacdonald@cbrm.ns.ca>; Glenn M. Paruch <gmparuch@cbrm.ns.ca>; Stephen T. Parsons <stparsons@cbrm.ns.ca>; James D. Edwards <jdedwards@cbrm.ns.ca>; Kenneth B. Tracey <kbtracey@cbrm.ns.ca>; Darren F. O'Quinn <dfoquinn@cbrm.ns.ca>; Lorne F. Green <lfgreen@cbrm.ns.ca>
Cc: Marie J. Walsh <mjwalsh@cbrm.ns.ca>; Wayne H. Macdonald - Eng <whmacdonald@cbrm.ns.ca>; Jennifer L. Campbell <jlcampbell@cbrm.ns.ca>; Michael E. Ruus <meruus@cbrm.ns.ca>; John F. MacKinnon <jfmackinnon@cbrm.ns.ca>; Demetri Kachafanas <DKachafanas@cbrm.ns.ca>; Tyler Mattheis <tyler@capebretonpartnership.com>
Subject: NOVA COPPER / BEECHMONT

Dear Mayor and Council:

I am writing to update you further on Nova Copper's progress in developing safe, responsible, local copper mining to support the energy transition to net zero.

Our communication with Indigenous communities, which began three years ago, continues. Nova Copper is committed to working directly and respectfully with First Nations to ensure maximum economic, social and environmental benefits accrue to Indigenous communities, consistent with Treaty obligations set out by the Crown that date back to the 1700s.

Our company continues to meet with Cape Bretoners who are embracing the potential that safe, responsible copper exploration and mining can bring to the Island. Jack Wall and the Cape Breton Island Building Trades Council has been an effective advocate for local workers and Nova Copper is excited to continue our dialogue with progressive organizations like the Building Trades Council to ensure local workers secure employment opportunities that will be realized through safe, responsible copper mining.

Nova Copper is grateful for the support extended to us by the Cape Breton Partnership as we have safely undertaken our copper exploration activities over the last several years on the land we have under lease from Cape Breton Regional Municipality. Our upcoming phase of exploration will attract additional $ millions right away in investment to Cape Breton over the next 12 to 24 months, if successful, which we anticipate we will be, the investment will dramatically increase prior to seeking approval for any production. If at a later date, production is approved, the long term values will be measured in billions.

Nova Copper will continue to respect all applicable health, safety and environmental standards. It is noteworthy that through our exploration work to date, there have been no complaints from the community and therefore no sanctions have been taken by appropriate authorities.

The fight against climate change depends on copper. Electric vehicles, wind turbines, solar panels – many of the major tools to address the climate emergency rely on copper. There is a global shortage of copper. Communities that do not welcome safe, responsible copper mining will be abdicating their responsibility to act on climate change.

Based on the positive feedback Nova Copper has received to date, we are confident that Cape Breton Regional Council will do the right thing, support action on climate change and provide the clarity and certainty that we need to deliver economic, social and environmental benefits to all Cape Bretoners.

Harry Cabrita

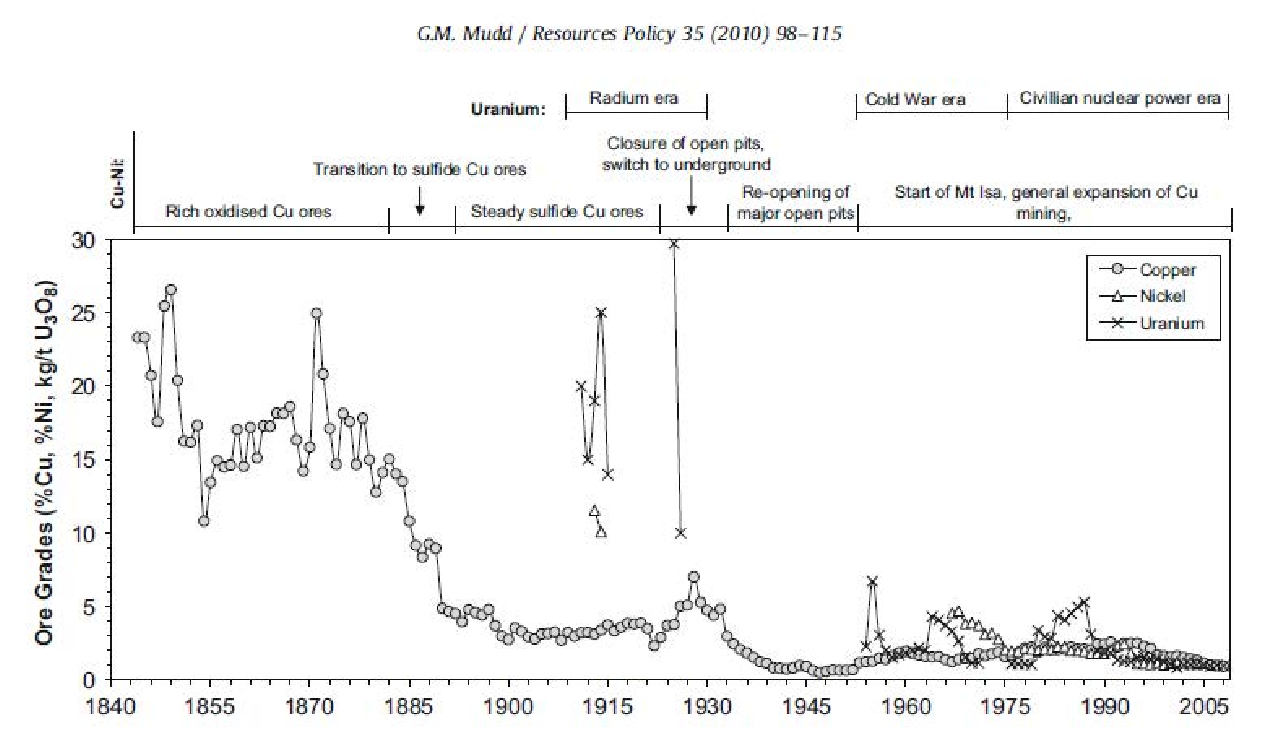
President & CEO / NOVA COPPER INC.

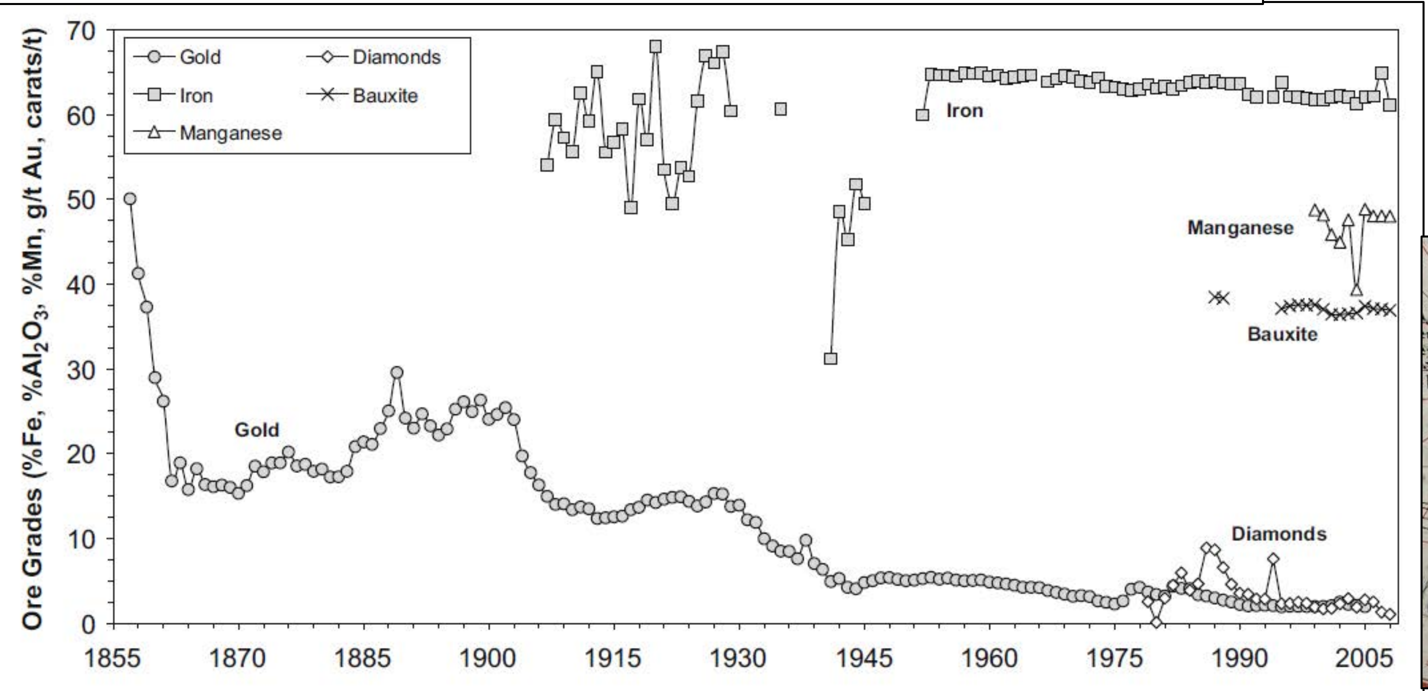
Tel: +1 (902) 880 7888

CRITICAL METALS EXPLORATION: hc@novacopper.ca

WEB: novacopper.ca

Email from Harry Cabrita, CEO of Nova Copper to the Mayor and Council of the Cape Breton Regional Municipality: "Communities that do not welcome safe, responsible copper mining will be abdicating their responsibility to act on climate change."





The remaining ore deposits are heavily depleted.

Grades of remaining ore deposits:
Copper: 0.64%
Lithium: 0.60%
Gold: 0.00008% (0.8 grams per metric ton)

Ancient, high-grade deposits are long gone.

The Remaining Ore Body Becomes Tailings (Toxic Waste)

Tailings are the wet, crushed rock particles that remain after the commodity of value has been removed. Typically, the tailings are permanently stored behind a dam constructed out of mine waste.

Santo Antônio Dam,
Morro do Ouro Mine near
Paracatu, Minas Gerais, Brazil
Largest gold mine in Brazil

Waste rock is the rock that must be removed to reach the ore body.
Typically, for every ton of copper ore, 1.86 tons of waste rock are produced.

For gold, waste-to-metal ratio is 3,046,349 (by far, the highest for any commodity).

Copper: Waste-to-metal ratio = 513

Lithium: Waste-to-metal ratio = 1634

Description of RMR results

Table S4. Summary of results for each component of the rock-to-metal ratio by mineral commodity.

Mineral commodity	Number of operations (n)	Coverage (% of global production)	Global quantities (million metric tons)										Global ratios				
			A* = B* + C*	B*	C*	A/A*	A = B + C	B	C	D	E	F	B/C	D/C*	E/D	F/E	A/F
			Total material extracted	Total waste rock removed	Total ore mined	Average revenue allocation	Attributable total material extracted	Attributable waste rock removed	Attributable ore mined	Commodity contained in processed ore	Commodity contained in concentrate produced	Finished commodity production	Waste to ore ratio	Ore grade	Concentrat or recovery rate	Smelter/ refinery recovery rate	Rock to metal ratio
Aluminum	68	93%	535	220	314	100%	534	220	314	80.34	76.32	74.79	0.70	25.56%	95%	98%	7
Chromium	23	100%	505	344	161	93%	469	316	152	44.60	29.43	26.49	2.08	27.69%	66%	90%	18
Cobalt	47	76%	496	322	174	18%	87	59	28	2.07E-01	1.13E-01	1.02E-01	2.12	0.12%	55%	90%	[illegible]
Copper	431	94%	11,451	7,528	3,922	78%	8,881	5,771	3,110	25.18	19.22	17.32	1.86	0.64%	76%	90%	513
Gallium	4	99%	53	35	18	12%	6	4	2	6.79E-04	4.29E-04	4.07E-04	1.90	0.0037%	63%	95%	15,604
Gold	777	79%	13,870	9,819	4,051	52%	7,182	5,323	1,859	3.16E-03	2.62E-03	2.36E-03	2.86	0.00008%	83%	90%	3,046,349
Iridium	20	97%	397	276	121	2%	9	6	3	9.68E-06	7.94E-06	7.32E-06	1.97	0.00001%	82%	92%	1,253,310
Iron	428	78%	10,155	6,732	3,423	99%	10,062	6,665	3,398	1,534	1,185	1,090	1.96	44.81%	77%	92%	9
Lithium	16	100%	110	92	18	94%	103	87	16	1.06E-01	7.00E-02	6.30E-02	5.53	0.60%	66%	90%	1,634
Magnesium	50	90%	9	-	9	100%	9	-	9	1.03	1.00	0.90	0.00	11.78%	97%	90%	10
Molybdenu	67	100%	6,388	4,173	2,216	20%	1,276	831	445	4.88E-01	3.00E-01	2.85E-01	1.87	0.02%	62%	95%	4,478
Nickel	69	100%	963	586	377	57%	545	314	231	3.08	2.42	2.18	1.36	0.82%	79%	90%	250
Palladium	32	93%	556	388	168	25%	141	97	44	2.59E-04	2.14E-04	2.05E-04	2.20	0.00015%	83%	96%	688,473
Platinum	35	94%	559	391	168	27%	149	103	45	2.28E-04	1.85E-04	1.78E-04	2.28	0.00014%	81%	96%	834,932
Rhodium	23	98%	438	299	139	10%	45	31	14	2.82E-05	2.31E-05	2.17E-05	2.12	0.000020%	82%	94%	2,074,800
Ruthenium	21	96%	423	298	125	2%	7	4	2	3.87E-05	3.14E-05	2.98E-05	1.98	0.00003%	81%	95%	218,490
Silicon	1	85%	9	5	4	100%	9	5	4	4.13	3.97	3.16	1.22	98.33%	96%	80%	3
Silver	627	100%	12,812	8,977	3,834	4%	570	388	182	3.90E-02	2.68E-02	2.55E-02	2.13	0.0010%	69%	95%	22,378
Tantalum	14	100%	57	38	18	30%	17	7	10	1.34E-02	2.14E-03	1.91E-03	0.72	0.073%	16%	90%	8,946
Tin	43	100%	657	24	633	99%	650	20	630	4.54E-01	3.20E-01	2.91E-01	0.03	0.072%	70%	91%	2,231
Titanium	35	90%	592	119	473	61%	359	34	325	7.54	4.04	3.64	0.11	1.59%	54%	90%	99
Tungsten	64	99%	115	69	46	68%	78	45	33	1.10E-01	8.03E-02	7.23E-02	1.34	0.24%	73%	90%	1,081
Vanadium	9	99%	380	274	106	19%	73	53	21	1.32E-01	7.02E-02	5.50E-02	2.53	0.12%	53%	78%	1,336
Zinc	284	78%	1,552	1,087	465	40%	625	444	181	11.83	9.78	8.80	2.45	2.55%	83%	90%	71
Zirconium	19	97%	356	31	325	47%	167	17	151	8.19E-01	6.75E-01	6.07E-01	0.11	0.25%	82%	90%	275
Overall[a]	1,928[b]						32,055	20,845	11,210	1,714	1,333	1,229	1.86	8.04%	78%	92%	26

Waste rock dump from gold mining

What Can Go Wrong?: Catastrophic Failure of the Tailings Storage Facility

Mount Polley mine
British Columbia, Canada
August 4, 2014
24 million cubic meters of tailings
Destruction of salmon habitat

Samarco mine
Mariana, Minas Gerais, Brazil
November 5, 2015
32 million cubic meters of tailings
19 deaths
Runout of 637 kilometers

Córrego do Feijão mine
Brumadindo, Minas Gerais, Brazil
January 25, 2019
9.7 million cubic meters of tailings
272 deaths

Skunk Camp Tailings Storage Facility for Resolution Copper Mine

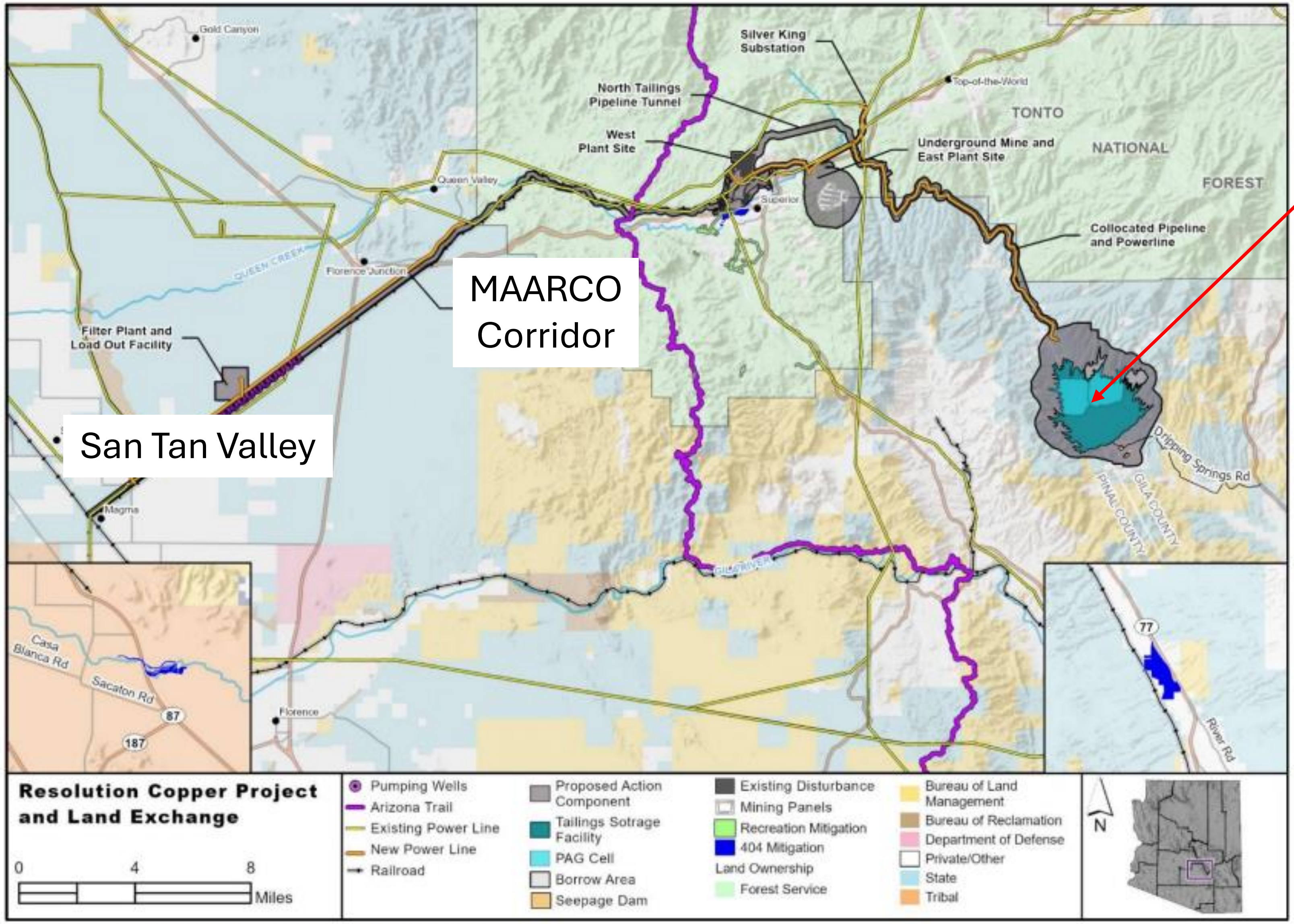
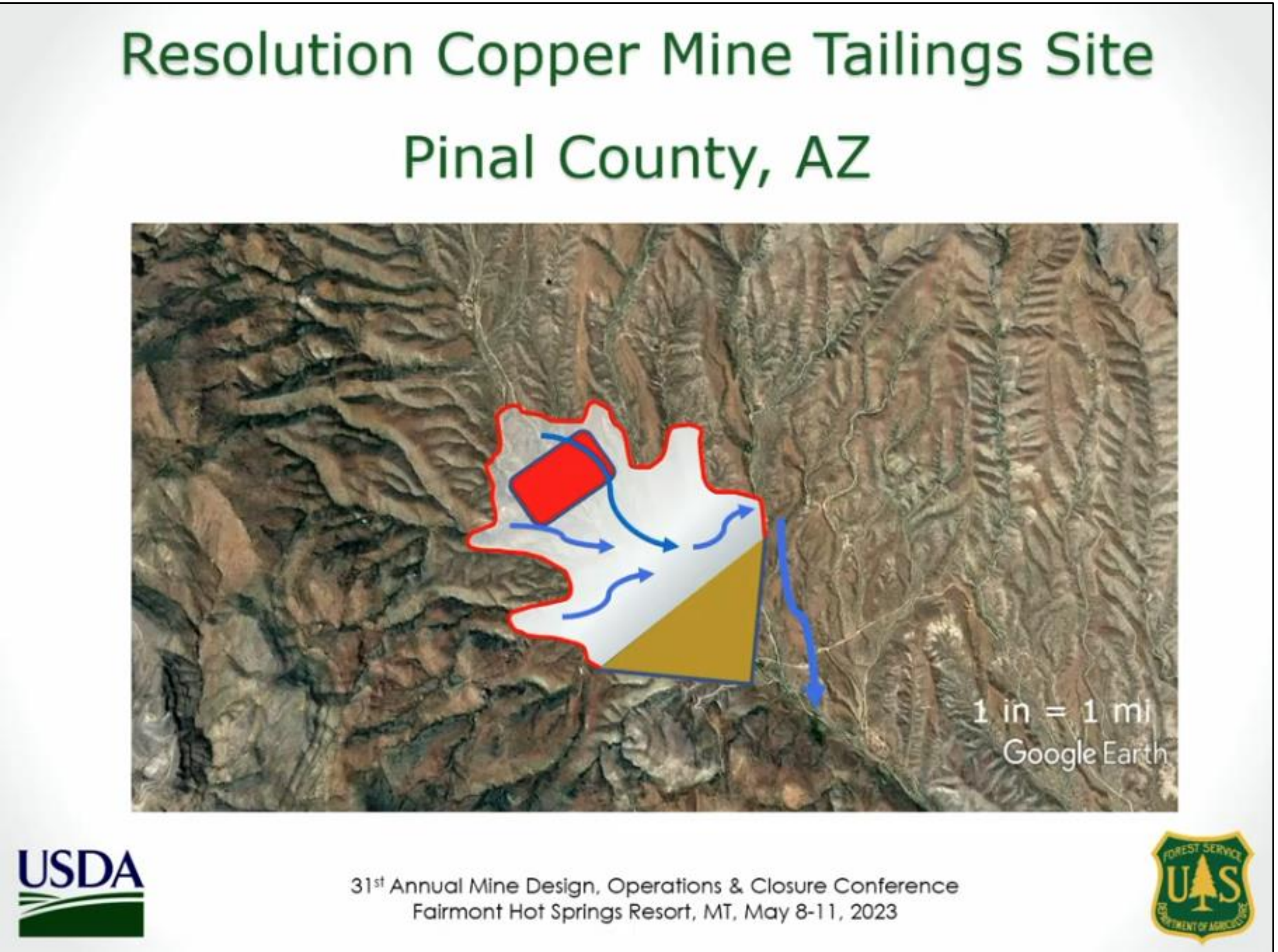


Figure ES-7. Alternative 6 – Skunk Camp (preferred alternative)

- Permanent storage of 1.37 billion tons of toxic tailings
- Dam would be 490 feet high and 3 miles long
- Dam would be constructed out of the toxic tailings themselves

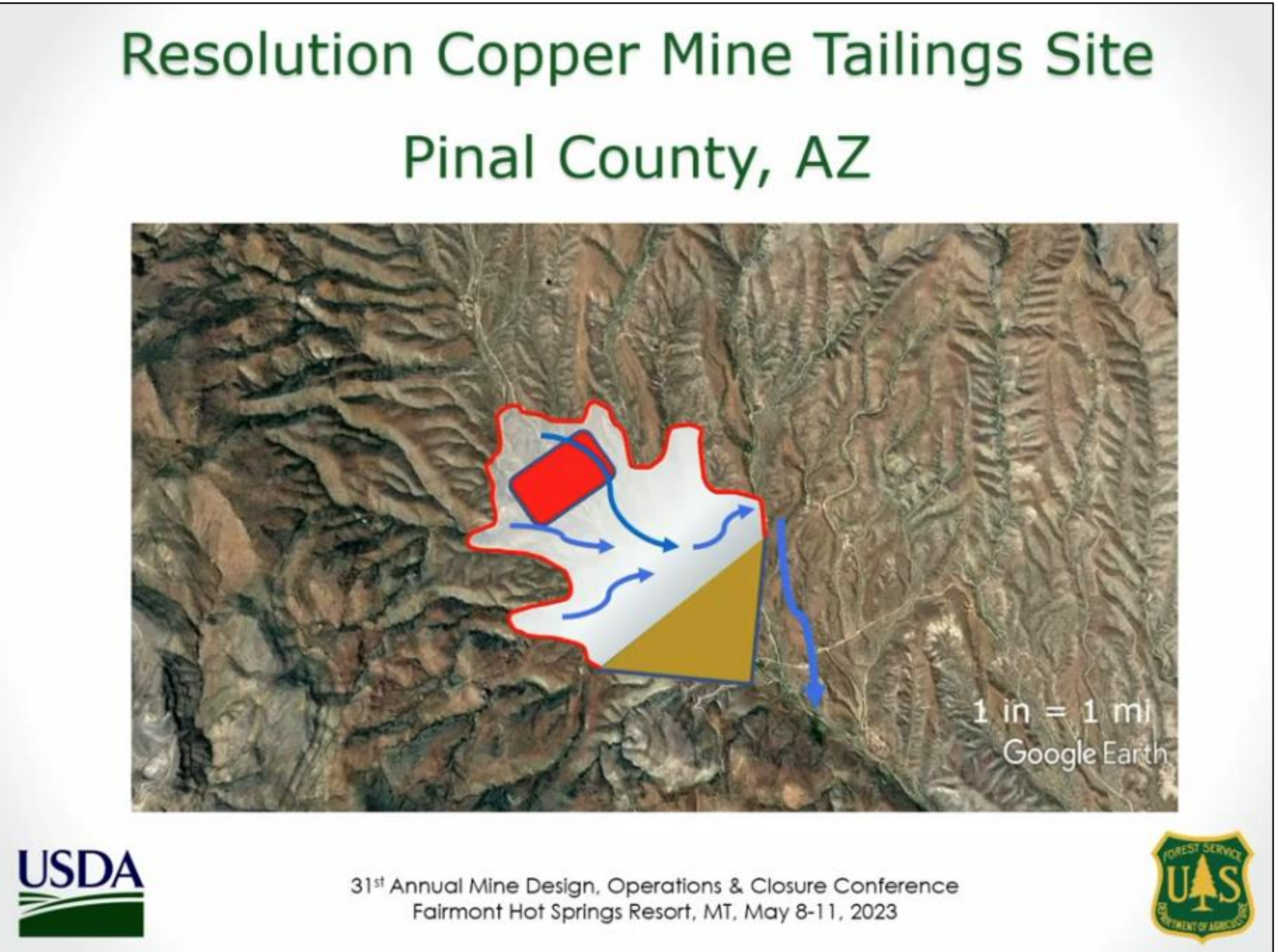
Peter Werner, Senior Mining Engineer, U.S. Forest Service, Explained the Mechanism of Failure of the Skunk Camp Tailings Storage Facility



Although Peter Werner is one of the preparers of the Final Environmental Impact Statement (FEIS), this information is not available in the FEIS.

2023 Presentation
https://www.youtube.com/watch?v=P-ix0NES5jo
17:38 - 18:54

Mechanism of Failure of the Skunk Camp Tailings Storage Facility



"Let's go down to the desert where Resolution is proposing to put its tailings impoundment. Right there at the bottom of the drainage, blocking all of those side drainages, this thing at full buildout is going to be about 4000 acres. Distances across it are measured in miles. It's going to contain 1.4 billion tons of tailings. The design is to route all of the run-on from the surrounding areas over the top of this thing and out a notch over by the left abutment. What makes this especially problematic is they are nesting 220 million tons of highly concentrated pyrite tailings in the center of this thing. So, this needs to be very robust and immune from any kind of degradation."

The FEIS Predicts that, following Failure of the Skunk Camp Facility, the Tailings will Travel 268 Miles with a Range of 83-868 Miles

Table 3.10.1-6. Empirical estimates of a hypothetical failure

Distance to:	Alternatives 2 and 3 – Near West Location*	Alternative 4 – Silver King Location (filtered)†	Alternative 5 – Peg Leg Location	Alternative 6 – Skunk Camp Location	For Comparison: Actual Mount Polley Failure‡	For Comparison: Actual Fundão Failure‡
Calculated release volume (million cubic meters)	243 (136–436)	220	243 (136–436)	243 (136–436)	23.6	45
Calculated downstream distance traveled (miles)	277 (85–901)	~1–2.5	209 (65–669)	268 (83–868)	4.4	398

Source: Larrauri and Lall (2018). Calculations can also be run at https://columbiawater.shinyapps.io/ShinyappRicoRedo/.

Notes: Values shown reflect the median predicted result; values in parentheses indicate the range defined by the 25th and 75th percentiles.

Key parameters: Total facility volume at buildout = 1 billion cubic meters; Embankment height: Alt 2 (520 feet/158 m); Alt 3 (510 feet/155 m); Alt 5 (310 feet/94 m); Alt 6 (490 feet/148 m). Mount Polley and Fundão comparisons taken from Bowker (2019).

* Alternative 3 modeled as Alternative 2

† Alternative 4 uses filtered tailings and the empirical method is not applicable. A 220-million-cubic-meter release was modeled using the USGS LaharZ model instead.

‡ The Mount Polley release represented 32 percent of the total facility volume; the Fundão release represented 82 percent of the total facility volume.

The great distance is a consequence of the dam height and the volume of stored tailings.

The distance of 868 miles is not the absolute worst-case scenario, but the 75th percentile.

The distance from Skunk Camp to the Mexican border is 425 miles along the Gila and Colorado Rivers

- The distance from the Mexican border to the Gulf of California is another 85 miles
- In 40% of model outcomes, the tailings will travel to the Mexican border during the initial event.
- In 36% of model outcomes, the tailings will travel to the Gulf of California during the initial event.
- After the initial event, normal fluvial processes will transport the tailings to the Gulf of California.

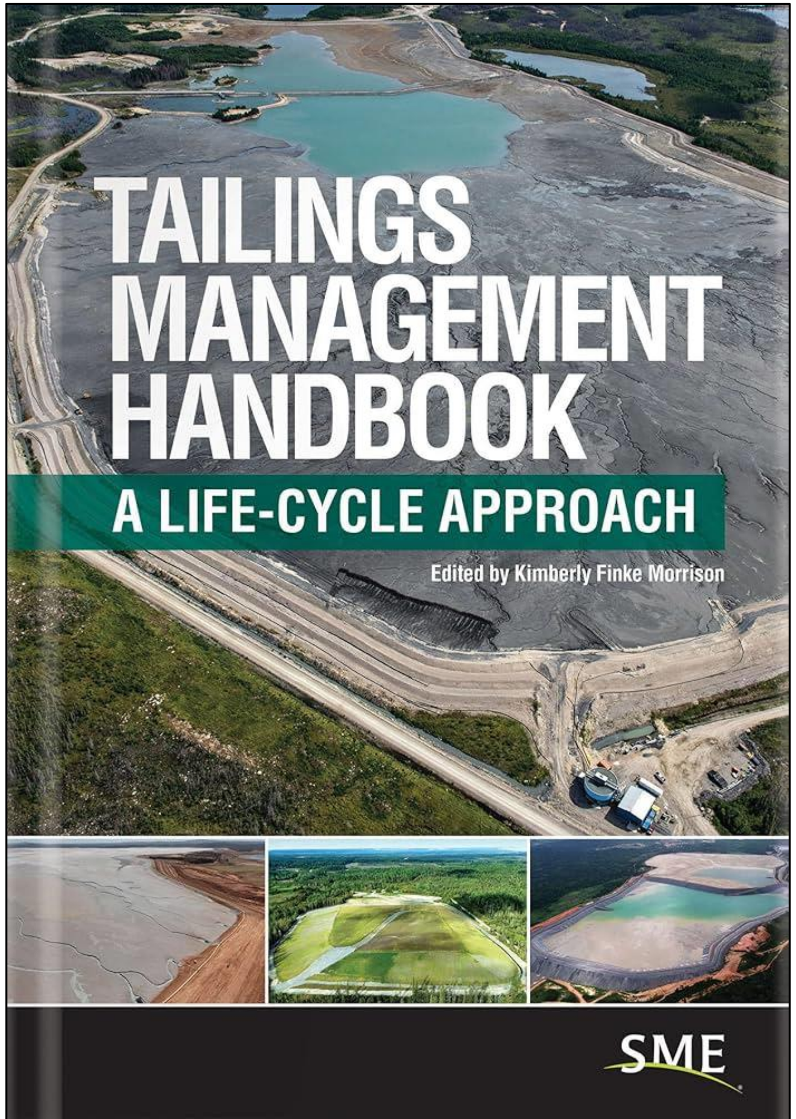
Tailings Storage Facilities are Permanent

When water retention dams are no longer needed, they must be dismantled. They cannot simply be abandoned until they collapse with no maintenance.

Tailings dams can never be dismantled.
Will they be monitored, inspected, maintained, and reviewed forever?
If not, all future generations will have to worry about the eventual collapse of the tailings dam.

Dismantling of the Glines Canyon Dam, Olympic National Park, Washington, USA

Mining Industry Position: Tailings Storage Facilities Require Maintenance in Perpetuity



Society for Mining, Metallurgy and Exploration (SME):

"The mining industry has a significant challenge in that these TSFs [Tailings Storage Facilities] will last for perpetuity. Unfortunately, humans have no experience in designing facilities to last forever, so responsible tailings management is required for as long as the TSF exists."

U.S. Forest Service Position: Tailings Storage Facilities Require Maintenance in Perpetuity

The party's over, now what?

by Peter Werner

Technological advances in mine equipment and milling processes have enabled mining companies to exploit ever lower grades of ore. The result has been larger disturbances, greater volumes of waste, a complex web of infrastructure, and an overall trend toward mega projects that can extend over several square kilometers. This explosive growth in a mining operation's disturbance footprint provokes an obvious question: What is it going to cost to reclaim all of this? At face value, this can be an enormous financial liability for a company, but since the timing of reclamation may be years in the future for many operations, these costs can be heavily discounted, thereby limiting the burden on the corporate balance sheet. Nonetheless, mining companies are eager to remove these liabilities as quickly as possible; conversely, regulators want assurance reclamation will, in fact, occur. How might one bridge these competing interests? Navigating the practical and financial requirements of a post-closure landscape requires foresight, judgement and assumptions; however, companies that do not adequately plan for these future expenditures when there is no offsetting income stream will likely face some difficult decisions. Simple risk analysis tools and utilizing the time value of money can help bring some clarity to this end-of-mine life phase.

Photo courtesy of Montana Department of Environmental Quality

Landusky Mine in Montana: five years after reclamation.

Peter Werner, member SME, is a mining engineer in the U.S. Department of Agriculture (USDA), Bozeman, MT, email peter.werner@usda.gov.

Asset retirement obligations

Moody's Ratings published in 2024 a review of asset retirement obligations (AROs) for 24 of the largest listings in its metals and mining sector (Moody's Ratings, 2024). Some of the results should be reason for alarm. One of the more remarkable findings was the increase in ARO obligations compared to long-term debt. The total outstanding reclamation obligations for the companies surveyed are the equivalent of 42 percent of their combined long-term debt. Moody's estimated compounded annual growth in AROs since 2018 at 9.7 percent and rising, and if current trends continue, AROs could eclipse long-term debt within 10 years. For one company, its combined outstanding AROs represented more than 50 percent of its most recent annual revenue. The growing significance of a company's AROs in combination with servicing long-term debt, ties up capital that otherwise could be used for the exploration and development of new properties, putting a company at risk from nonincome-producing assets.

Some companies are taking steps to reduce this liability by reclaiming parts of their operations during active mine life, but the contribution to the bottom line is often minimal, especially for operations with an openpit or multiple active waste rock dumps or a tailings impoundment, all of which may be needed right to the end of mine life. Alternatively, through discounting these future financial obligations or offloading expiring properties, companies are able to avoid a balance sheet awash in red ink and maintain a favorable credit rating. Despite these maneuvers, ever-increasing AROs point to a future day of reckoning for somebody, whether it is a company that cannot meet its ARO obligations or the regulator who inherits an environmental liability.

How long is long term?

It is not uncommon for a mine plan to include language that states post-closure monitoring and maintenance will continue

"The U.S. Forest Service recently conducted a risk assessment of a mine facility on National Forest System lands using the failure modes and effects analysis (FMEA) methodology … The FMEA showed recurrent natural processes (such as wildfire, storm runoff, vegetation succession, slope creep, freeze thaw cycling) were the principal drivers behind eventual reclamation failure over an extended time horizon. This is due to the incremental degradation of individual component performance leading to more acute nonperformance and eventual system-wide breakdown … **The FMEA participants concluded that the natural processes that drove risk would always be present and would slowly degrade the reclaimed facilities over time. The only solution to maintaining system performance was a commitment to site care and maintenance — well, forever … There is no expiration date on reclamation integrity, and mining companies should recognize their post-closure care and maintenance obligations may last far longer than they have currently planned for and, in some instances, may be a forever proposition.**"

“For closure, system failure is inevitable…”

Closure answers

1. Over what duration should the closure design remain effective?
   Effectiveness is unlikely to be maintained much beyond 100 years

2. How effective should it be (what system failure probability)?
   System failure probabilities much less than 50/50 are unlikely to be achievable over performance periods greater than 100 years

3. What return period for design events is consistent with (1) and (2)?
   Even for return periods associated with MCE and PMF events, system failure probability approaches 1.0 after several hundred years

- *For closure, system failure is inevitable ($p_f \rightarrow 1.0$), so closure risk depends solely on failure consequences (1D)*
- *Conventional (2D) FMEA does not properly handle closure*

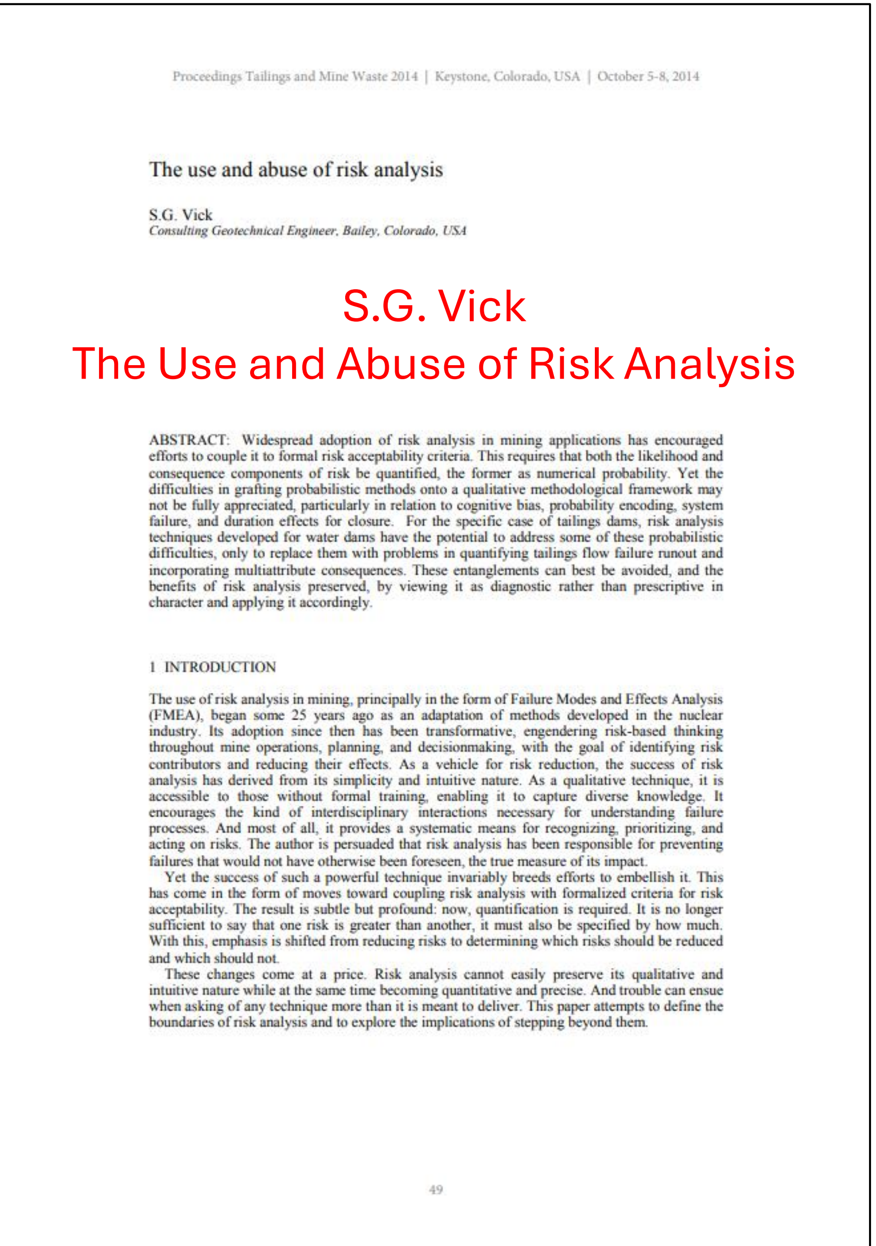
TAILINGS AND MINE WASTE 2014

Planning, Design, and Analysis of Tailings Dams

Steven G. Vick

BiTech PUBLISHERS LTD
Vancouver, B.C. Canada

"System failure must be accepted as inevitable …"



Proceedings Tailings and Mine Waste 2014 | Keystone, Colorado, USA | October 5-8, 2014

The use and abuse of risk analysis

S.G. Vick
Consulting Geotechnical Engineer, Bailey, Colorado, USA

S.G. Vick
The Use and Abuse of Risk Analysis

ABSTRACT: Widespread adoption of risk analysis in mining applications has encouraged efforts to couple it to formal risk acceptability criteria. This requires that both the likelihood and consequence components of risk be quantified, the former as numerical probability. Yet the difficulties in grafting probabilistic methods onto a qualitative methodological framework may not be fully appreciated, particularly in relation to cognitive bias, probability encoding, system failure, and duration effects for closure. For the specific case of tailings dams, risk analysis techniques developed for water dams have the potential to address some of these probabilistic difficulties, only to replace them with problems in quantifying tailings flow failure runout and incorporating multiattribute consequences. These entanglements can best be avoided, and the benefits of risk analysis preserved, by viewing it as diagnostic rather than prescriptive in character and applying it accordingly.

1 INTRODUCTION

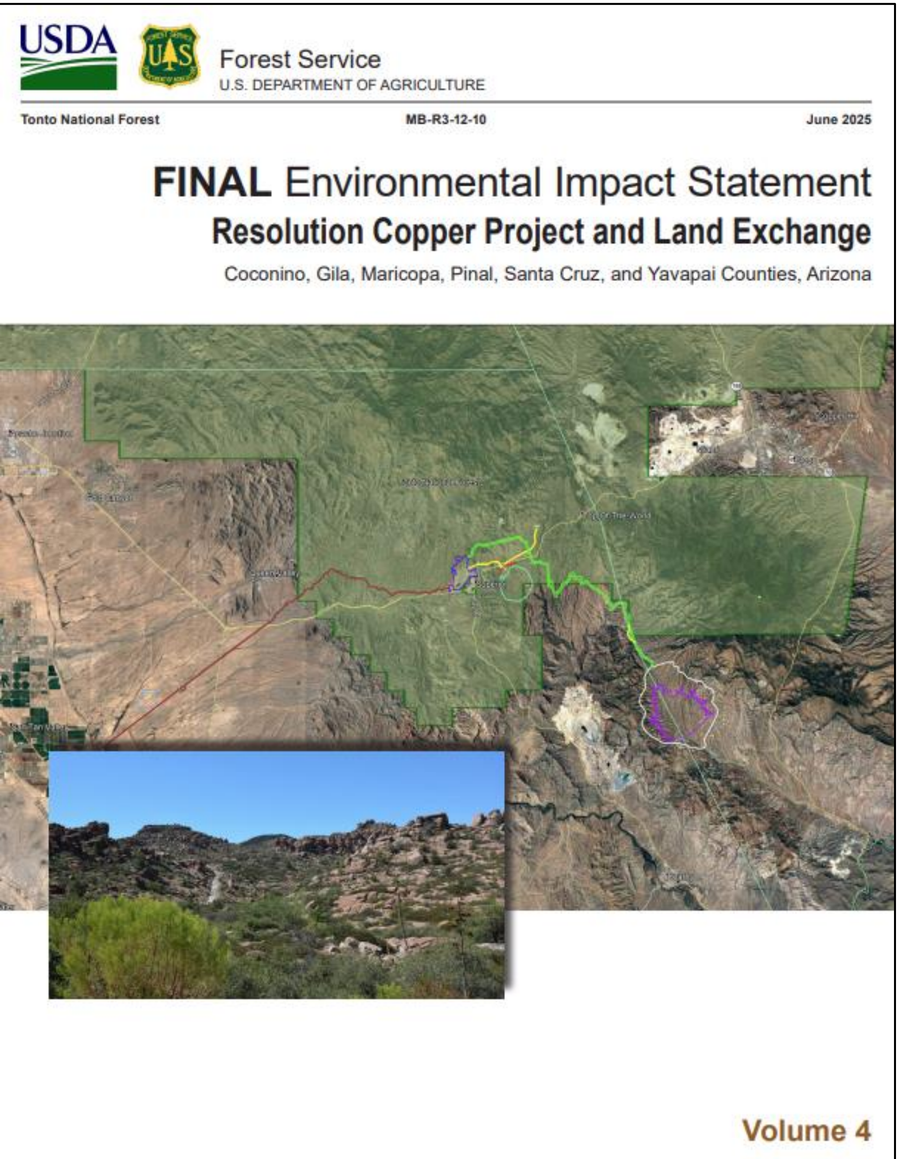
The use of risk analysis in mining, principally in the form of Failure Modes and Effects Analysis (FMEA), began some 25 years ago as an adaptation of methods developed in the nuclear industry. Its adoption since then has been transformative, engendering risk-based thinking throughout mine operations, planning, and decisionmaking, with the goal of identifying risk contributors and reducing their effects. As a vehicle for risk reduction, the success of risk analysis has derived from its simplicity and intuitive nature. As a qualitative technique, it is accessible to those without formal training, enabling it to capture diverse knowledge. It encourages the kind of interdisciplinary interactions necessary for understanding failure processes. And most of all, it provides a systematic means for recognizing, prioritizing, and acting on risks. The author is persuaded that risk analysis has been responsible for preventing failures that would not have otherwise been foreseen, the true measure of its impact.

Yet the success of such a powerful technique invariably breeds efforts to embellish it. This has come in the form of moves toward coupling risk analysis with formalized criteria for risk acceptability. The result is subtle but profound: now, quantification is required. It is no longer sufficient to say that one risk is greater than another, it must also be specified by how much. With this, emphasis is shifted from reducing risks to determining which risks should be reduced and which should not.

These changes come at a price. Risk analysis cannot easily preserve its qualitative and intuitive nature while at the same time becoming quantitative and precise. And trouble can ensue when asking of any technique more than it is meant to deliver. This paper attempts to define the boundaries of risk analysis and to explore the implications of stepping beyond them.

"Regardless of the return period selected for design events, the cumulative failure probability will approach 1.0 for typical numbers of failure modes and durations. This has major implications. For closure conditions, the likelihood component of risk becomes unimportant and only the consequence component matters … This counterintuitive result for closure differs so markedly from operating conditions that it bears repeating. In general, reducing failure likelihood during closure—through more stringent design criteria or otherwise—does not materially reduce risk, simply because there are too many opportunities for too many things to go wrong. In a statistical sense, all it can do is to push failure farther out in time. System failure must be accepted as inevitable, leaving reduction of failure consequences as the only effective strategy for risk reduction during closure."

The Resolution Copper FEIS includes no plan for perpetual maintenance, nor even any Emergency Preparedness and Response Plan


USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Tonto National Forest MB-R3-12-10 June 2025

FINAL Environmental Impact Statement
Resolution Copper Project and Land Exchange
Coconino, Gila, Maricopa, Pinal, Santa Cruz, and Yavapai Counties, Arizona

Volume 4

"However, full emergency planning is premature, given that those efforts are specific to the downstream residents and community, and the facility would not begin operation—at best—for at least a decade. This remains a requirement for any facility built on Federal land, and while this would not include Alternative 6 [the Preferred Skunk Camp Alternative], emergency planning also is a specific requirement of the recently adopted Global Industry Standard on Tailings Management … Alternative 6: As facility would ultimately be located on private land, the Forest Service would not have authority to require these specific design standards."

Water Use vs. Water Consumption vs. Water Footprint

Water Use = Rate at which water circulates through the mining operation

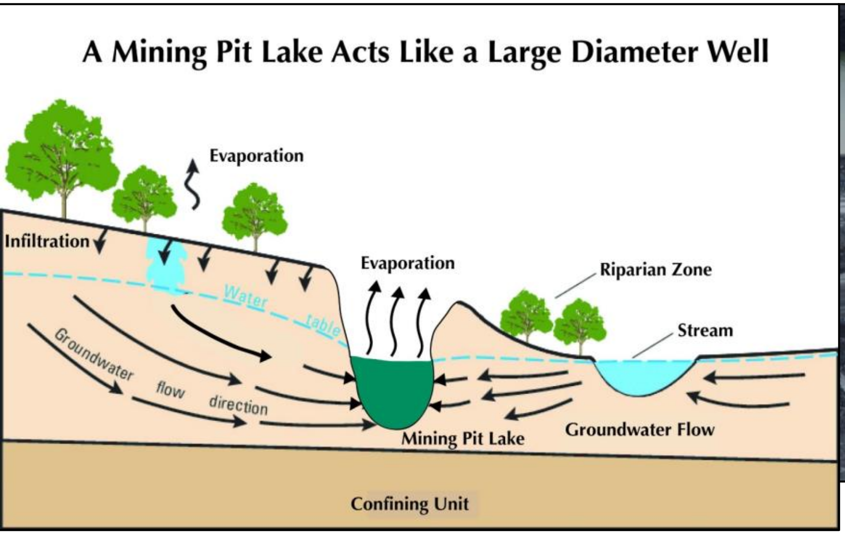
Water Consumption = Rate at which make-up water is withdrawn from groundwater or surface water sources =
Rate at which water is lost due to evaporation, incorporation into mine waste, incorporation into the end product, or returned to a different watershed from which it was withdrawn

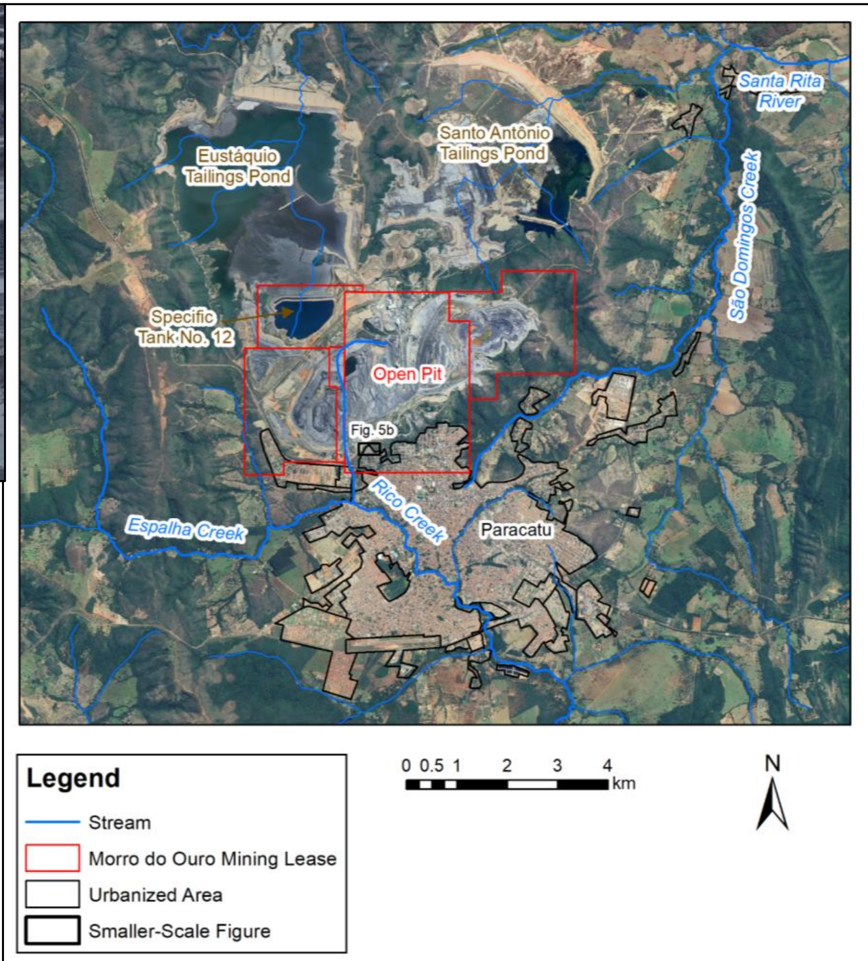
Water Footprint includes water consumed in generating electricity, manufacturing reagents, etc.

The above definition of water consumption is incomplete.

Alternative Definition: Water Consumption is Water that has been Taken Away from some other Consumer (Person or Ecosystem)

Water pumped from an open pit or underground galleries should count as water consumption





The open pit at the Morro do Ouro mine in Brazil is 5 kilometers long, 2 kilometers wide, and 400 meters deep. Kinross Gold does not report the rate of pit dewatering or count it as water consumption.

Water that is returned to the environment or left in a degraded / unusable state should count as water consumption

Because the pit lake evaporates and continuously draws in more groundwater, the consumption and degradation of water is continuous and permanent.

Pit lake at Anaconda mine, Nevada

Precipitation and surface runoff should count as water consumption

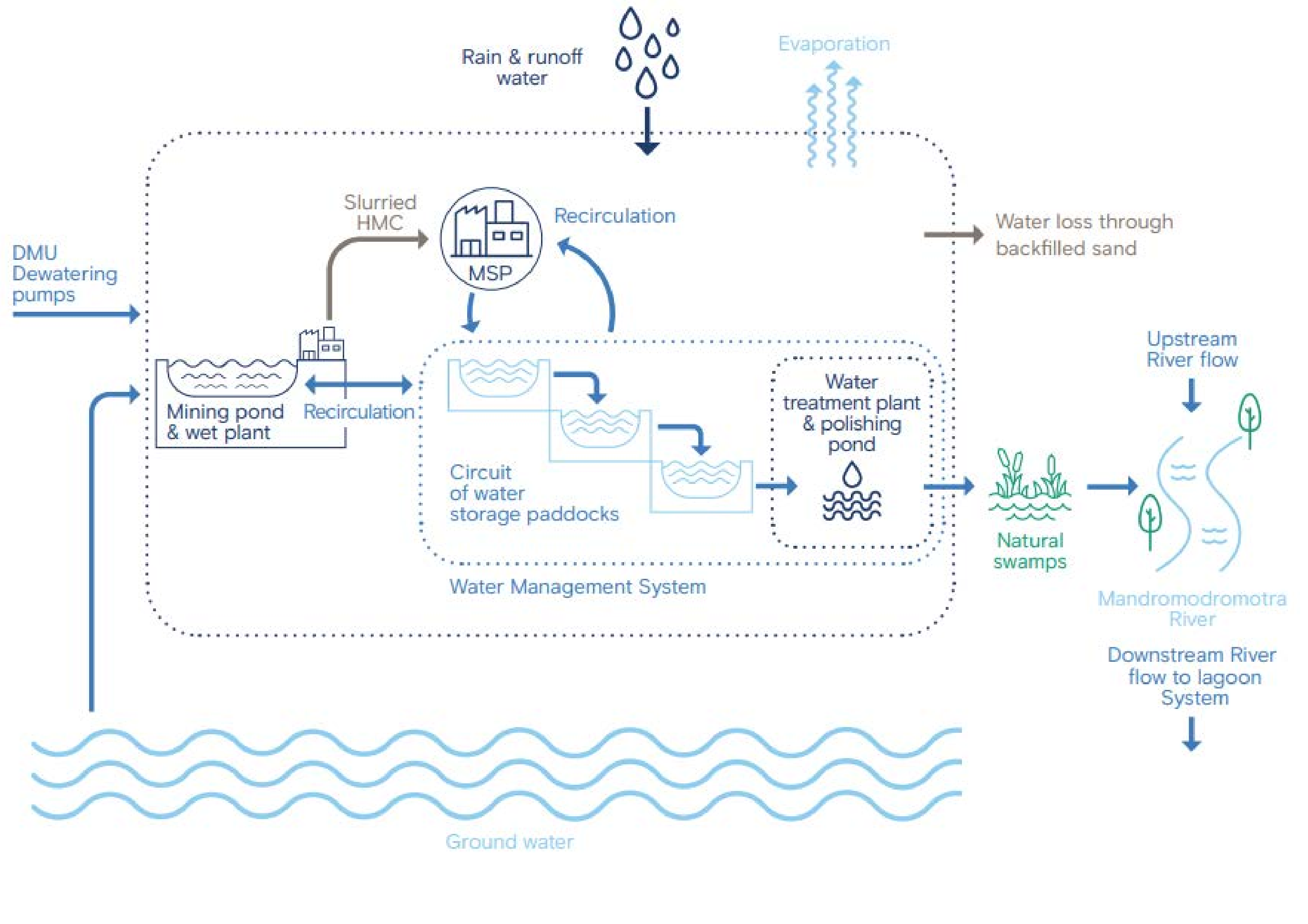


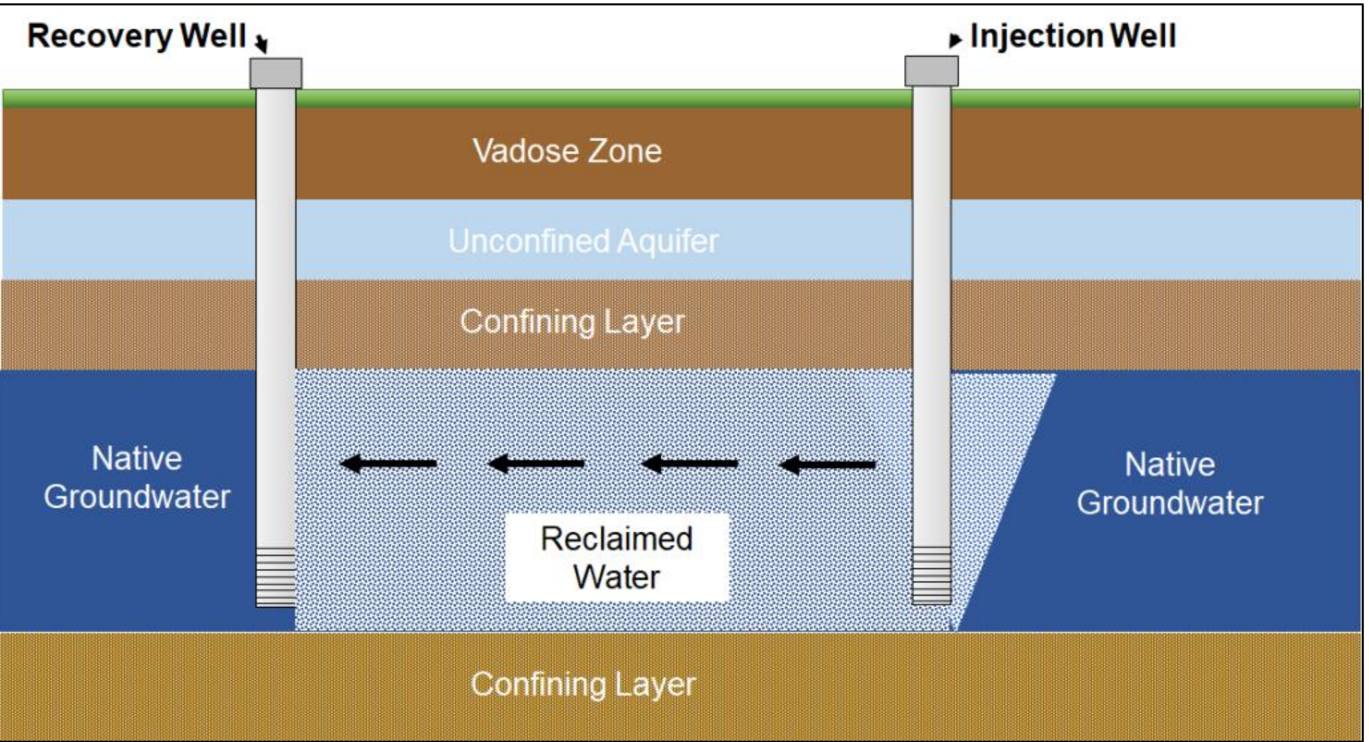
Figure 4: QMM simplified water flow diagram

Rio Tinto claims zero water consumption at the QMM mine in Madagascar, although the diagram shows the input of precipitation, surface runoff, and shallow groundwater to the mining operation

Diagram from "QMM Water Report—2021-2023"

Reinjecting wastewater to a different aquifer from which the groundwater was withdrawn should count as water consumption

- Well owners withdraw groundwater from a particular aquifer (not just from groundwater in general)
- Nearly all aquifers discharge into surface water (streams, lakes, wetlands, springs). A particular aquifer discharges into a particular surface water body.

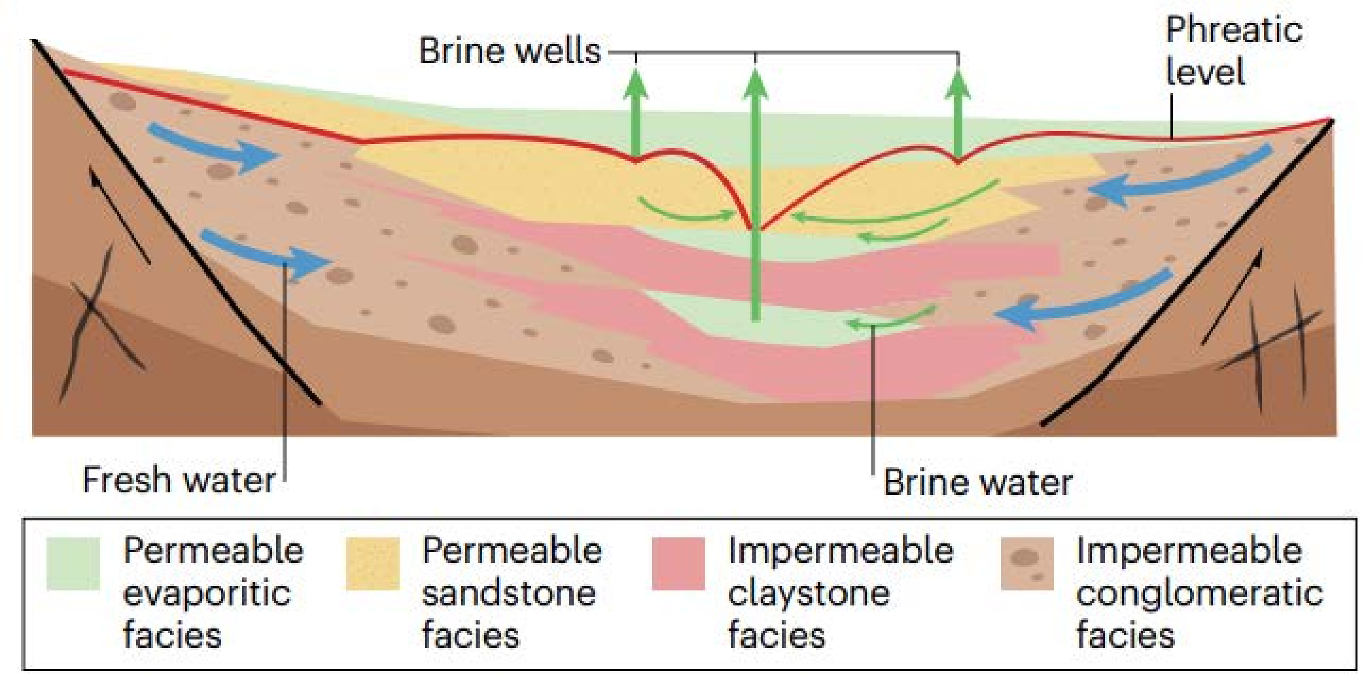


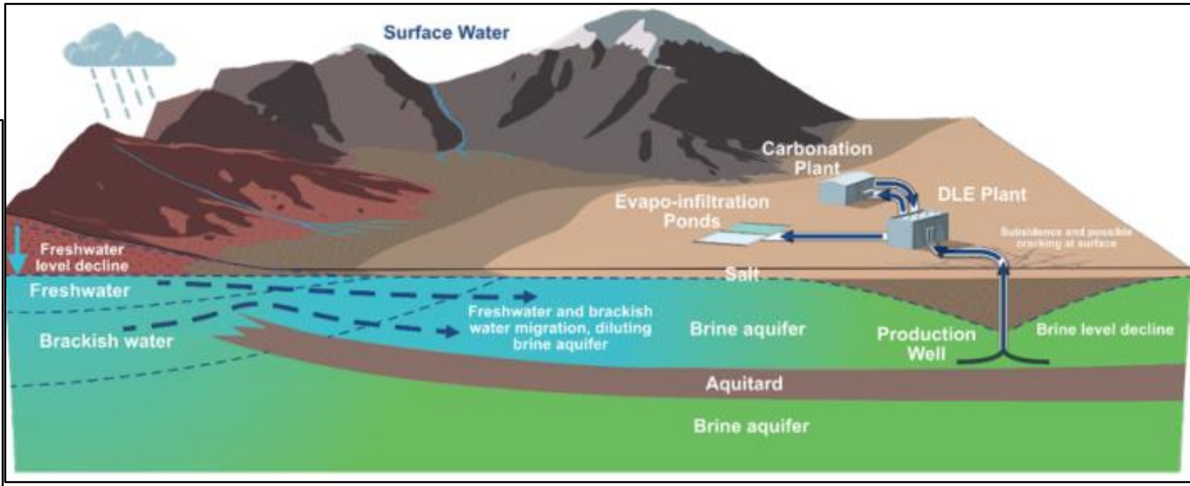
Proposed Paradox Lithium Project (Utah): The State Engineer has ruled that reinjecting spent brine into a different aquifer does not count as water consumption.

In Managed Aquifer Recharge, water is returned to the same aquifer from which water is withdrawn (which would be the only logical thing to do).

Consumption of brine should count as water consumption

- Pumping brine aquifers draws fresh water out of other aquifers
- Most brine aquifers discharge at surface sites to saline springs, streams and wetlands
- It is problematic to regard a naturally-occurring water body as “nothing” or “useless” or “waste”





Most brine aquifers are fed by fresh water that becomes brine as evaporation concentrates the salts or as the fresh water mixes with the brine.

The Generation of Toxic Waste is the Driver for the Consumption of Fresh Water

A mixture of water and tailings from the ore processing plant is hydraulically discharged from the crest of the tailings dam into the tailings pond.

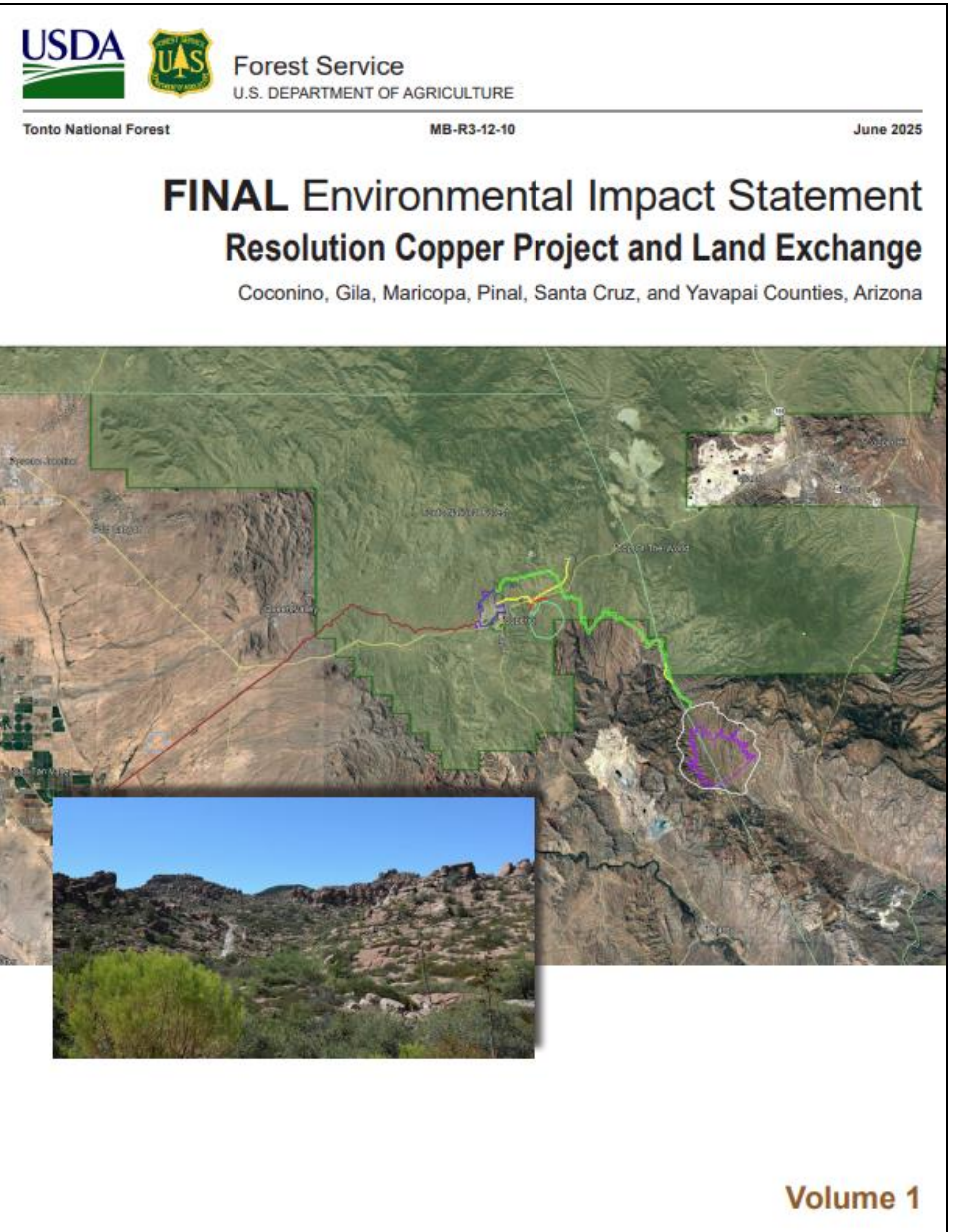
Cobre Dam, Riotinto Copper Mine, Spain

Tailings settle out of suspension and the supernatant water is pumped back into the mining operation

Evaporation from the tailings pond and the permanent entrainment of water in tailings are the major sources of water consumption.

Cobre Dam, Riotinto Copper Mine, Spain

Predictions of Water Consumption in the Resolution Copper FEIS



"Alternative 6 – Skunk Camp remains the Lead Agency's preferred alternative … This alternative would need about **540,000 acre-feet of groundwater** pumped from the Desert Wellfield through the life of the mine … The wells located within the MARRCO corridor have been referred to by various terms during the NEPA process and in this EIS, including 'pumping wells,' 'recovery wells,' and 'the Desert Wellfield'."

540,000 acre-feet = water consumption by 83,000 Arizona residents over 40 years

Resolution Copper Plans for Even Greater Pumping Capacity

General Plan of Operations

May 9, 2016

Resolution Copper Mining

"The current recovery well field design consists of approximately 30 wells with a capacity of approximately 400 gpm (25 L/s) each along the MARRCO Corridor between the CAP canal and SR 79."

30 x 400 gpm x 40 years = **774,000 acre-feet** = water consumption by 118,000 Arizona residents over 40 years

Arizona State Land Department Objects to Groundwater Pumping

Katie Hobbs
Governor

ARIZONA STATE LAND DEPARTMENT
1110 West Washington Street | Phoenix, AZ 85007
(602) 542-4631

Robyn Sahid
Commissioner

August 4, 2025

Reviewing Official, Regional Forester
333 Broadway Boulevard SE
Albuquerque, New Mexico 87102

RE: **Arizona State Land Department's Objection to the Resolution Copper Project and Land Exchange and Project-Specific Forest Plan Amendment**
Tonto National Forest
Ericka Luna, Deputy Forest Supervisor

The Arizona State Land Department ("ASLD") is a cooperating agency that issued comments on the Draft Environmental Impact Statement ("Draft EIS") by letter dated November 7, 2019. A primary focus of those comments was the impact of the substantial withdrawal of groundwater from the aquifer beneath the Superstition Vistas Planning Area ("SVPA"), which contains 275 square miles of Arizona State Trust Land ("STL"). The proposed "Desert Wellfield" from which groundwater will be withdrawn extends roughly four miles and is surrounded by STL.

ASLD manages a perpetual land trust consisting of over 9 million acres of STL that the United States granted to Arizona upon statehood in the Arizona Enabling Act. The grant is a "solemn promise" by the United States to the State to support the beneficiary purposes set out in the Enabling Act, primarily public education. ASLD has a trust obligation derived from the Enabling Act and Arizona Constitution to manage all those lands for the benefit of the trust's beneficiaries.

The SVPA is a projected location of substantial future expansion of the Phoenix metropolitan area with hundreds of thousands of future residents. Development of the SVPA could bring billions of dollars of additional income to the beneficiaries of the State Land Trust.

Specific Issue: Groundwater Decline and Subsidence in the SVPA

ASLD has significant concerns with the withdrawal of an estimated 544,858 acre-feet of groundwater in the SVPA over the life of the mine, 6.7 percent of all the groundwater available in the entire East Salt River Valley, much of which is STL. Not only will the recent recovery of 60 to 85 feet of depth to groundwater in the area be halted, it will be significantly reversed near the Desert Wellfield, reaching a maximum drawdown of 199 feet at the end of mine operations.

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"ASLD has significant concerns with the withdrawal of an estimated 544,858 acre-feet of groundwater in the SVPA [Superstition Vistas Planning Area] over the life of the mine, 6.7 percent of all the groundwater available in the entire East Salt River Valley, much of which is STL [State Trust Land] … The Project's groundwater withdrawals will have significant adverse impacts on the regional aquifer underlying 275 square miles of STL. The FEIS modeling of [Preferred] Alternative 6 shows a maximum drawdown of approximately 200 feet in the center of the wellfield below current water levels, with declines of approximately 100 – 130 feet at its edges. This pumping associated with Alternative 6 would decrease the likelihood that groundwater could be used for new development in the future as hydrological and legal contexts continue to evolve, adding additional groundwater depletion to an already stressed groundwater sub-basin … The value of the as yet undeveloped STL would thus suffer from the potential additional water supply obstacles to already committed uses, which could delay or eliminate demand for STL."

Groundwater Depletion is Irreversible

Katie Hobbs
Governor

ARIZONA
STATE LAND DEPARTMENT
1110 West Washington Street | Phoenix, AZ 85007
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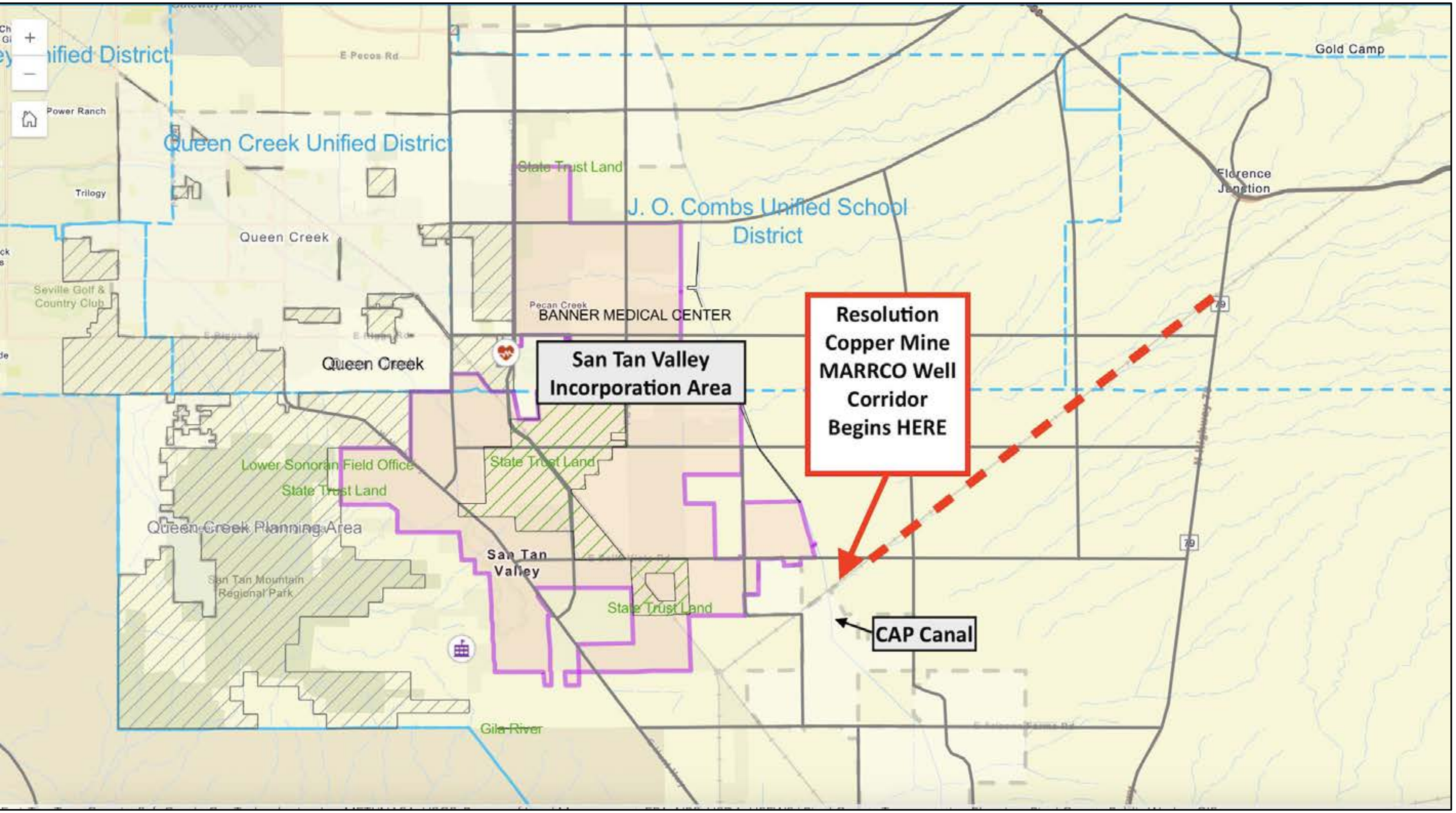
"The Final EIS estimates that Alternative 6 would result in roughly 24 to 50 inches of subsidence within two miles of the Desert Wellfield, which encompasses approximately 20 square miles or 12,840 acres of STL. The Final EIS reasons that subsidence will occur where groundwater withdrawal causes the water table to drop below its historically recorded lows. The removal of this water will cause the compaction of the earth from which the water has been removed … Moreover, as the Final EIS acknowledges … subsidence is irreversible, the ground will not return to its prior level, and the ground will not be able to store as much water as it had previously … the ongoing process of subsidence and the potential formation of earth fissures in the subsidence area present a risk to the future development of the land and the value of STL in the area. As noted in the Final EIS, earth fissures can directly damage structures as well as infrastructure including roads, utility lines, wells, and canals."

Are San Tan Valley and Resolution Copper competing for the same groundwater?



Is Resolution Copper even being realistic in predicting its water consumption?

Emerman Report: Resolution Copper has under-predicted their water consumption by a factor of about three.

Projected Consumption of Electricity and Water by the Proposed Resolution Copper Mine, Arizona

Dr. Steven H. Emerman, Malach Consulting, LLC, 785 N 200 W, Spanish Fork, Utah 84660, USA, E-mail: SHEmerman@gmail.com, Tel: 801-921-1228

Report to Arizona Mining Reform Coalition, submitted March 11, 2019
Revision submitted March 31, 2019

LIGHTNING SUMMARY

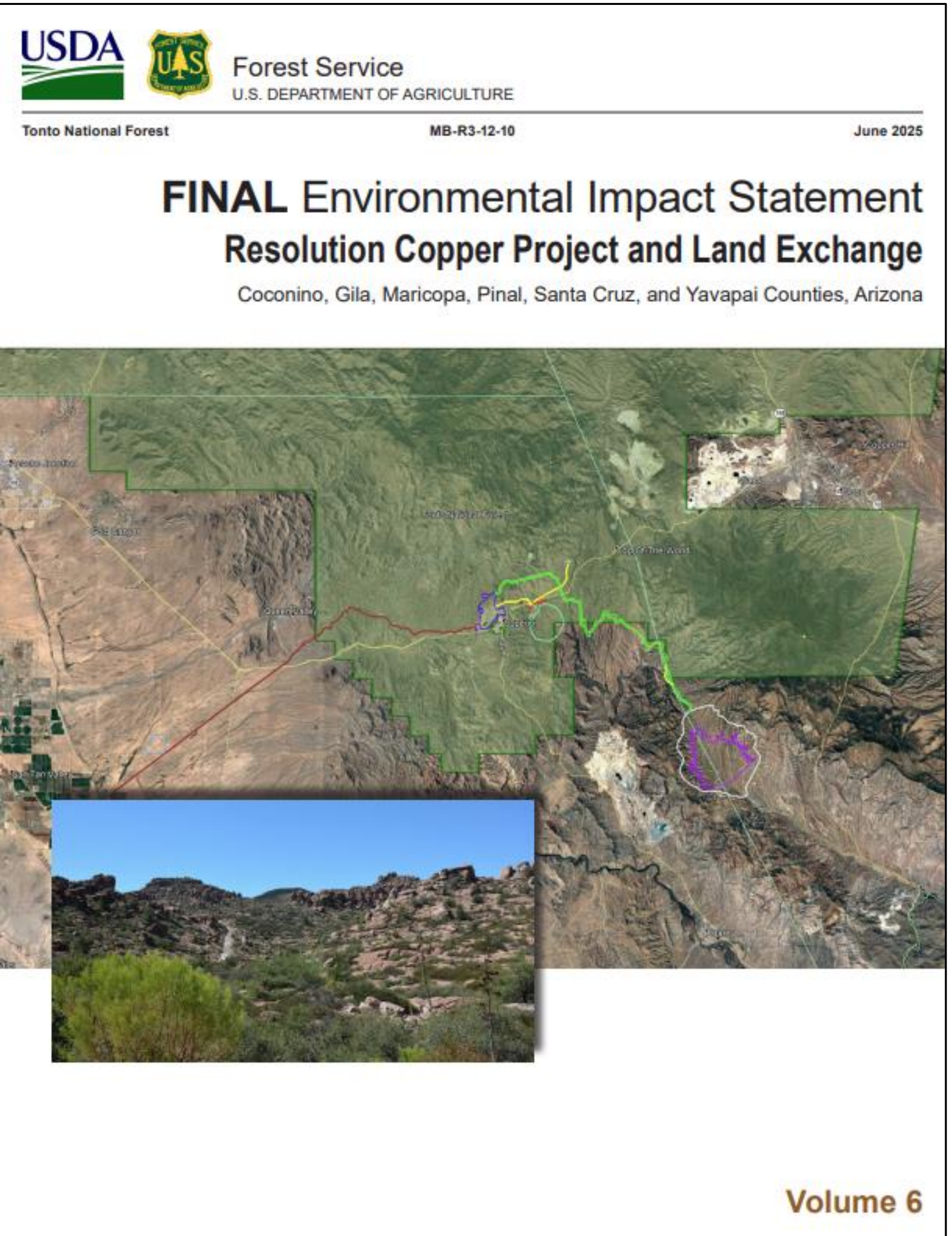
Rio Tinto has provided no estimate of the electricity consumption of the proposed Resolution Copper Mine, Arizona, but it can be shown to be 3% and 22% of the peak power capacity of the Salt River Project under the best-case and worst-case scenarios, respectively. Rio Tinto has estimated water consumption of only 15,700 acre-feet per year (about one-third of industry standards) while using conventional technologies for water efficiency.

ABSTRACT

The underground Resolution Copper Mine that is being proposed by Rio Tinto in Arizona would process 150,000 metric tons of ore per day from an ore body at a depth of 5000-7000 feet with a grade of 1.47%. The objective of this study was to evaluate the projected consumption of electricity and water by the proposed mine. Rio Tinto has provided no information about electricity consumption, except that power would be supplied by the local grid of the Salt River Project. Based on the depth, grade, and production rate, the projected electricity consumption would be 236 MW. However, the discovery of geothermal water while drilling the primary access shaft could result in additional electricity consumption of 24 MW solely for mine dewatering and refrigeration under the best-case scenario and 1650 MW under the worst-case scenario, corresponding to total electricity consumption of 260 MW and 1900 MW, which are 3% and 22%, respectively, of the peak power capacity of the Salt River Project. Rio Tinto has estimated water consumption as 15,700 acre-feet per year and a possible maximum of 20,000 acre-feet per year, with the Central Arizona Project as the primary water source. However, based on the grade and production rate, water consumption of 50,000 acre-feet per year would be more typical for the copper mining industry. Although Rio Tinto states that "the mine will be operated to maximize internal water reuse," the General Plan of Operations proposes only conventional technologies for water efficiency. These technologies would result in the export of cleaner tailings with 50% water, scavenger tailings with 35% water, and copper concentrates with 9% water, all of which are conventional industry standards. The export of water with the tailings alone would result in water consumption of 25,600 acre-feet of water per year. It is recommended that potential investors or partners seek clarification on the consumption and sources of electricity and water.

"Rio Tinto has estimated water consumption as 15,700 acre-feet per year and a possible maximum of 20,000 acre-feet per year … However, based on the grade and production rate, water consumption of 50,000 acre-feet per year would be more typical for the copper mining industry. Although Rio Tinto states that 'the mine will be operated to maximize internal water reuse,' the General Plan of Operations proposes only conventional technologies for water efficiency."

The FEIS Finds only One "Flaw" in the Analysis by Emerman

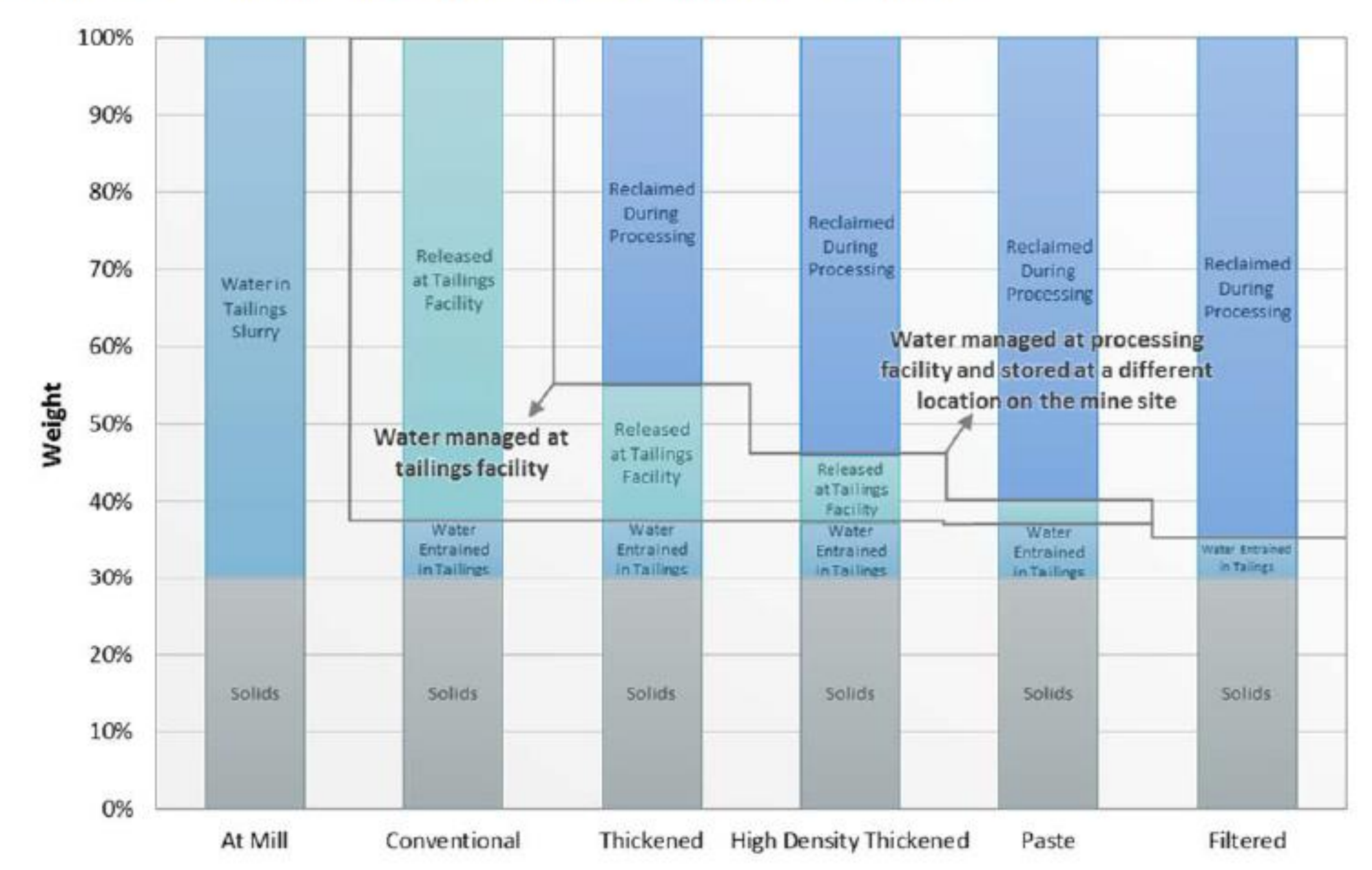


"The point made by these public comments is that this disclosed water use (16,682 af/yr) is less than that predicted by Dr. Emerman from literature estimates (50,000 af/yr) … A review of the same literature sources used by Dr. Emerman confirms the point made: Resolution Copper water use as disclosed is less than would be anticipated, based on other mines. However, Emerman fails to examine why this difference exists, but instead assumes it means the disclosure is flawed … the data sources used by Dr. Emerman fail to account for the type of tailings. Specifically, the Resolution Copper Project is using thickened tailings ranging from 50 to 65 percent solids, compared with 20 to 50 percent solids in a conventional tailings slurry … The review of the Emerman report demonstrates that the water difference identified by Dr. Emerman is due to use of this technology … In other words, the Resolution Copper Project uses less water than other mines because the proponent has incorporated enhanced technology (thickening) in order to reduce water use."

Note confusion between "water use" and "water consumption."

Conventional and thickened tailings consume the same amount of water

Figure 5.1 Comparison of Water Recovery for Tailings Technologies



- In both cases, 30 tons of solid tailings permanently entrain 7 tons of water.
- As long as there is exposed surface water, the evaporation is the same.
- Significant water savings occur only with filtered tailings.

Acid Mine Drainage

Red-brown color in discharge from dam drainage pipes **after** water treatment
Morro do Ouro Mine, Paracatu, Minas Gerais, Brazil

Identical color in water from hand-dug wells in village of Santa Rita (after addition of bleach)

Acid Mine Drainage: Quick Tutorial

Pyrite (iron sulfide) + oxygen + water → dissolved iron + sulfuric acid

- A sulfide ore contains sulfide minerals
- Sulfide minerals are typically stable when they are beneath the surface.
- Exposure to oxygen converts sulfide minerals to sulfuric acid.
- Oxidation of sulfide minerals releases the heavy metals that were part of the crystal structure.
- Increased acidity in streams causes release of heavy metals attached to stream sediments.
- Detrimental impact upon municipal and private water supplies and aquatic health



Left to right:
Pyrite (iron sulfide)
Galena (lead sulfide)
Sphalerite (zinc sulfide)

There are no examples of sulfide-ore mines that have been operated and closed without environmental pollution

The Minnesota Prove It First Bill and the Myth of Sulfide Ore Mining without Environmental Contamination

Steven H. Emerman, Ph.D., Malach Consulting, LLC, 785 N 200 W, Spanish Fork, Utah 84660, USA, Tel: 1-801-921-1228, E-mail: SHEmerman@gmail.com

Report prepared for Friends of the Boundary Waters Wilderness
Submitted February 1, 2023, Appendix added April 25, 2023

LIGHTNING SUMMARY

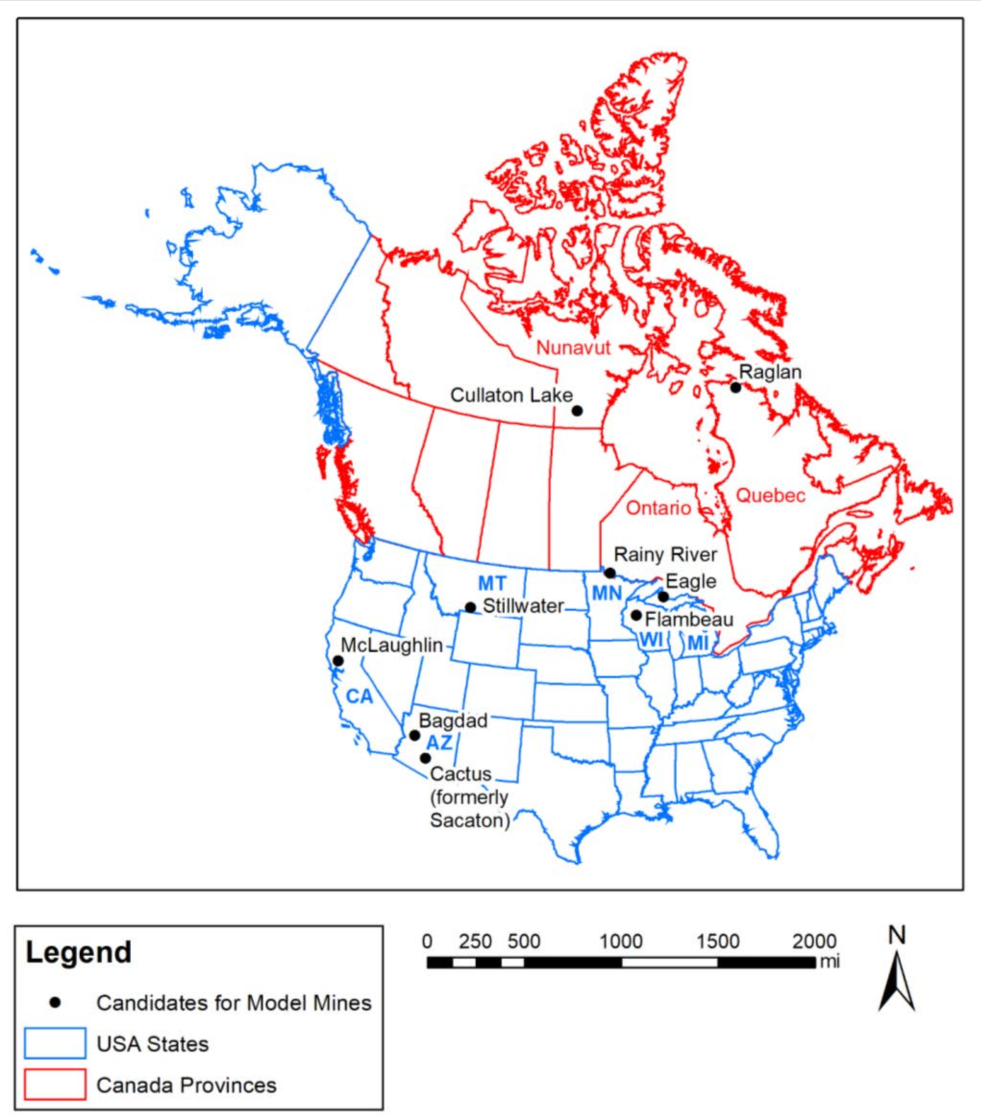
The Minnesota Prove It First Bill would prohibit sulfide ore mining unless it could be demonstrated that a sulfide ore mine in the USA and in a similar environment to the proposed mine site had operated for 10 years and had been closed for 10 years without environmental contamination. The nine candidates for model sulfide ore mines (Bagdad, Cactus, Cullaton Lake, Eagle, Flambeau, McLaughlin, Raglan, Rainy River, Stillwater) all have extensive records of environmental contamination. Although the Flambeau mine is often cited as a model sulfide ore mine, the Certificate of Completion of Reclamation merely certifies that the reclamation plan was carried out, but not that it was successful.

EXECUTIVE SUMMARY

Sulfide ore mining refers to the extraction of commodities from ore bodies that contain sufficient sulfide minerals for the generation of acid mine drainage. Despite the abundance of tools for the mitigation of acid mine drainage, some degree of environmental contamination has, thus far, been inevitable simply because there are so many ways for failure to occur. The concept that all mining, including sulfide ore mining, involves inevitable environmental contamination is widely assumed in the mining literature. In response, in 1997 the Wisconsin legislature enacted the "Moratorium on Issuance of Permits for Mining of Sulfide Ore Bodies," which prohibited sulfide ore mining in Wisconsin unless it could be demonstrated that, in the USA or Canada, at least one sulfide ore mine had operated for 10 years without environmental contamination and at least one sulfide ore mine had been closed for 10 years without environmental contamination. At various times, eight mines were formally or informally put forward as candidates for model sulfide ore mines, including:

1) Bagdad copper mine (Arizona)
2) Sacaton (now called Cactus) copper-silver-gold mine (Arizona)
3) Cullaton Lake gold mine (Nunavut)
4) Eagle nickel-copper mine (Michigan)
5) Flambeau copper-gold-silver mine (Wisconsin)
6) McLaughlin gold mine (California)
7) Raglan nickel mine (Quebec)
8) Stillwater palladium-platinum mine (Montana)

All eight candidates were discredited because they actually did have records of environmental contamination or, in some cases, insufficient monitoring data. The impasse was broken in favor of the mining industry only when the moratorium was repealed in 2017.



All candidates for sulfide-ore mines that have been operated and closed without environmental pollution actually have extensive records of pollution.

The Skunk Camp facility would separately store PAG tailings and “NPAG” tailings

PAG = Potentially Acid Generating

NPAG = Non-Potentially Acid Generating (but not really)

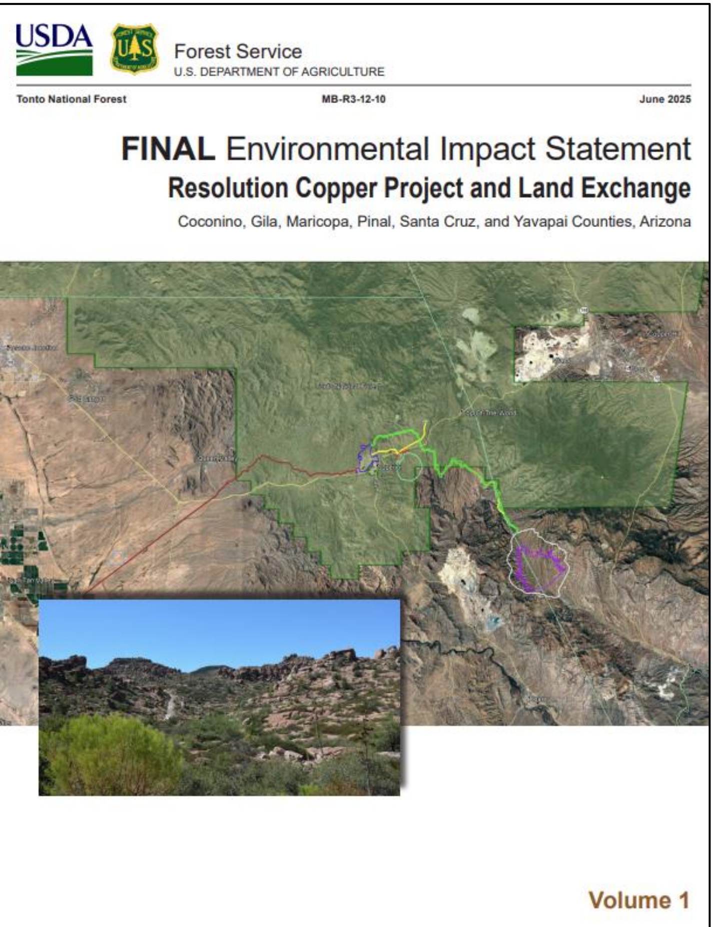
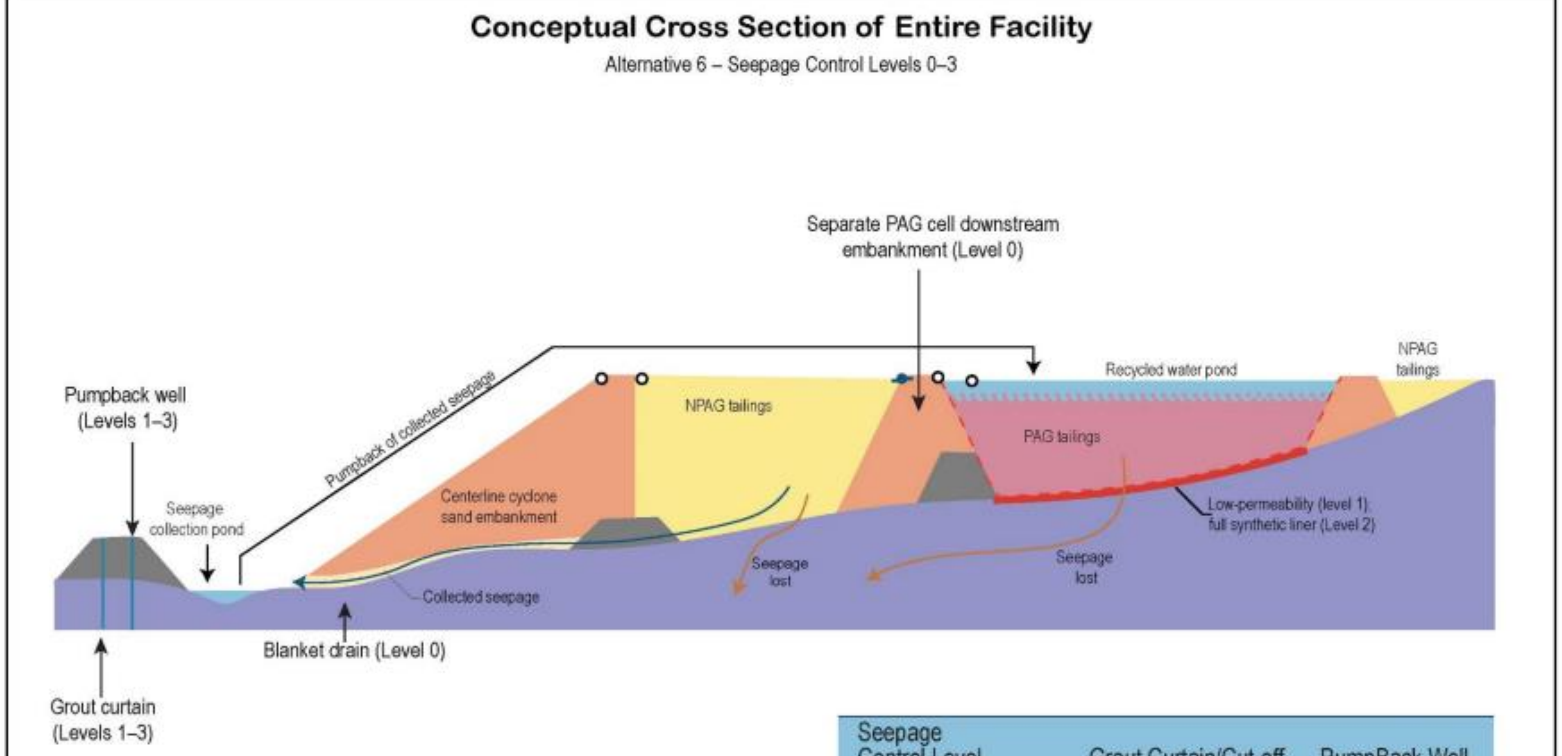


Table 3.7.2-6. Acid-generation classification of tailings samples

Tailings Type	Acid Generating	Non-acid Generating	Potentially Acid Generating
NPAG tailings (84% of total amount)	15%	41%	44%
PAG tailings (16% of total amount)	100%	0%	0%

“Samples of the tailings we call NPAG in reality are classified roughly as 15 percent acid generating, 41 percent non-acid generating, and 44 percent PAG … use of the term NPAG does not mean there is a complete lack of acid generation capacity in these samples.”

The “NPAG” tailings are treated as if they really were non-acid generating



Seepage Control Level	Grout Curtain/Cut-off	PumpBack Well
1	Depth of 70 feet	Depth of 20 feet
2	Depth of 100 feet	Depth of 70 feet
3	Depth of 100 feet	Depth of 100 feet

Figure 3.7.2-9. Alternative 6 seepage controls

- The dam will be constructed out of NPAG tailings, so that the dam itself will be a source of acid mine drainage.
- The PAG tailings will be kept submerged to avoid oxidation, but not the NPAG tailings.
- The PAG tailings will be gradually covered with NPAG tailings.

But doesn't the world need copper (battery metals, rare earth elements, hydrogen bombs, hypersonic missiles, artificial intelligence, etc., etc.)?

The "world" is not some kind of giant community meeting where everyone has an equal voice and everyone shares equally in all benefits, harms and risks.

Political decisions result from interactions among political actors, often with profound differentials in power.

Mines exist because people who will benefit from the mines have more power than those who will suffer the harms and bear the risks.

Who would benefit from the Resolution Copper mine?

- Rio Tinto is a British-Australian company.
- The largest shareholder in Rio Tinto is Chinalco (Aluminum Corporation of China), a Chinese state-owned company.
- The copper concentrate (including the critical minerals indium, silver, rhenium, tellurium, and bismuth plus the DOD strategic material molybdenum) would be shipped to China for processing.
- China could then sell or choose not to sell the refined copper plus other critical minerals and strategic materials back to the US

Thanks for listening!

Please feel free to contact Prof. Steven Emerman with any questions

E-mail: SHEmerman@gmail.com

MALACH CONSULTING