Appendix 4.4-B

Technical Memorandum: Calculation of Present Worth of Averted Dose from Corrective Action Alternatives

TECHNICAL MEMORANDUM

To: Brad Bingham, Closure Manager	**Date:** June 2022
From: Toby Wright Wright Environmental Services, Inc.	**Re:** **Homestake Mining Company** **Grants Reclamation Project** Calculation of benefit; present worth of averted dose from corrective action alternatives
Cc: File	

Introduction

The purpose of this technical memorandum is to document the technical bases and approach for estimating the present worth of the averted dose from implementing the corrective action alternatives presented in the ACL application to NRC for the Homestake Mining Company (HMC) Grants Reclamation Project (GRP), in Cibola County, New Mexico. The objective of this memo is to provide a technically sound and defensible quantitative assessment of the monetized benefits from averted radiological dose from the corrective action alternatives. The assessment is performed in accordance with NRC guidance in NUREG-1620 (NRC, 2003) and NUREG-1757, Vol.2, Rev.1 Appendix N (NRC, 2006).

Calculation of the averted dose from implementing groundwater corrective action is based on comparison of average conditions resulting from the No Action alternative (Alternative 1) to those conditions resulting from implementation of Alternative 2 and Alternative 3. Consistent with the exposure scenario used in the calculation of doses for Alternate Concentration Limits, a "resident gardener" exposure scenario is used for comparison among corrective action alternatives. These calculations are performed considering the methods presented in Section N.1.1 of Appendix N for NUREG-1757, Volume 2, Rev.1 (NRC, 2006). As stated in NUREG-1757, "*in the simplest form of analysis, the only benefit estimated from a reduction in the level of residual radioactivity is the monetary value of the collective averted dose to future occupants of the site*" (NUREG-1757, Vol. 2, Appendix N at N.1.1). It is understood that NUREG-1757, Volume 2, Revision 2 (NRC, 2020) remains draft for public comment and is not final at this time.

The potential radiological dose benefit from groundwater use at the GRP is related primarily to uranium concentrations. Characterization of the groundwater concentrations presented in the HMC Annual Performance Report (HMC, 2021) identifies that thorium-230 and combined radium-226 and 228 groundwater constituent concentrations above the License groundwater protection standards or above upgradient groundwater constituent concentrations are currently limited to the area directly beneath the Large and Small Tailings Piles (see figures and tables in Section 4 of HMC, 2021). There are no concentrations above the License groundwater protection standards or above upgradient groundwater constituent concentrations beyond the points of compliance (POC). These groundwater conditions and the concentration distribution of these relatively low mobility constituents are not anticipated to substantively change with approval of ACLs and cessation of groundwater corrective action. Therefore, there is no reduction in groundwater constituent concentrations or potential exposure concentrations for these two radiological parameters to be achieved through implementation of corrective action alternatives, and consequently, no benefit of averted dose to be derived.

Mapping of groundwater constituent concentrations of thorium-230 and combined radium-226 and 228 identify that these radionuclides are only present in groundwater at concentrations above their respective License groundwater protection standards directly under the tailings piles or for thorium-230 only, in two isolated wells at concentrations near their protective standards (see Appendix 4.1-B of the ACL application). Future transport of these constituents to the existing potential domestic well locations within the proposed control boundary and within the functional life of those wells at concentrations above the protective standards is not considered reasonable given the average groundwater flow rates (0.5 feet/day to 6 feet/day for the alluvial groundwater) and geochemical mobility in this geochemical environment (see Section 1.3.2 of ACL Application). Therefore, uranium is the only radioisotope considered herein to contribute to averted dose from groundwater corrective action.

However, the results, discussed later in this technical memorandum will indicate that the monetized benefit of averted collective dose from implementation of corrective action alternatives is so low that this omission or any uncertainty related to the other input quantities do not substantively change the order of magnitude of the calculated benefits.

Technical Approach

Appendix N of NUREG-1757, Volume 2, Revision 1 (ALARA Analyses) identifies methods for calculating the benefits from collective dose averted by implementing corrective actions, using the following equation.

(Equation 1) $B_{AD} = V_{AD} \text{ x } PW(AD_{Collective})$

Where B_{AD} = benefit from an averted dose for a remediation action, in current U.S. dollars

V_{AD} = value in dollars of a person-rem averted (see NUREG/BR–0058; NRC, 2017)

$PW(AD_{Collective})$ = present worth of a future collective averted dose

The most recent version of NUREG/BR-0058 (NRC, 2022) identifies a value for V_{AD} of $5,200 per person rem averted in 2014 dollars. This equates to approximately $6,250 in 2022 dollars using the Bureau of Labor Statistics inflation calculator (https://data.bls.gov/cgi-bin/cpicalc.pl?cost1=5200.00&year1=201401&year2=202201).

Equation 2 identifies the equation for calculating the present worth of future collective averted doses.

(Equation 2) $$PW(AD_{Collective}) = P_D \; x \; A \; x \; 0.025 \; x \; F \; x \; \frac{Conc}{DCGL_W} \; x \; \frac{1 - e^{-(r+\lambda)N}}{(r+\lambda)}$$

Where

P_D = population density for the critical group scenario in people/m^2;

A = area being evaluated in square meters (m^2), this is the area inside the proposed control boundary where groundwater concentrations may be accessed. 9.7 square miles

0.025 = annual dose to an average member of the critical group from residual radioactivity at the Derived Concentration Guideline Level ($DCGL_W$) concentration in rem/y;

F = effectiveness, or fraction of the residual radioactivity removed by the remediation action (assumed herein to be a value of 1, both alternatives assumed to achieve the complete reduction in residual radioactivity in groundwater);

Conc = average concentration of residual radioactivity in the area resulting from implementation of an alternative, activity per unit volume for groundwater; (pCi/L)

$DCGL_W$ = derived concentration guideline equivalent to the average concentration of residual radioactivity that would give a dose of 0.25 mSv/y (25 mrem/y) to the average member of the critical group, (pCi/L)

r = monetary discount rate in units per year (for doses averted within the first 100 years, a discount rate of 7% should be used. For doses averted beyond 100 years, a 3% discount rate should be used);

λ = radiological decay constant for the radionuclide in units per year; $\lambda = 0.693/T$, where T is 1/2 life of the isotope.

N = number of years over which the collective dose will be calculated. The averted dose is assumed to take place of a 30-year lifetime exposure period (N = 30 years)

Input Values

Affected Population – Site Critical Group (P_D x A)

The proposed control boundary encompasses an area of approximately 9.7 square miles. HMC currently owns a majority of the land within the proposed control boundary and is actively acquiring the remainder of the property within this boundary.

There is no current or projected use of groundwater on HMC owned land, other than for groundwater corrective action. There is no current use of affected groundwater within the proposed boundary, an alternative water supply is already in place and there is a State of New Mexico restriction on new or replacement wells covering the area within the proposed control boundary for the affected groundwater.

A review of the State Engineer's Office records identifies 19 active domestic well permits within the proposed control boundary, all of which have access to the existing municipal water supply lines (Figure 1). Each well is assumed to support a household of three persons. Current census data indicates in Cibola County has an average occupancy per household of approximately 2.67 persons. For this analysis, three persons per household were assumed. Therefore, the estimated population with a current exposure potential within the control boundary is estimated to be 57 persons. However, it is noted that once HMC completes the land acquisitions, there will be no exposed population within the proposed control boundary.

For the purposes of this analysis, it is assumed that all households within the proposed control boundary with active wells permits, even if they are connected to the municipal water supply, are the potentially exposed population. Projected water use demand calculations presented in Appendix 4.4-A of the ACL Application assume that domestic use for households connected to municipal water lines only use groundwater for outdoor uses (lawns and gardens) at 150 gallons per day per household (50 percent of full household use rate). However, as a conservative measure for this analysis, full household use and complete pathways are considered, consistent with a resident gardener exposure scenario.

Effectiveness (F)

It is conservatively assumed that the corrective actions will be fully effective; the effectiveness value (F) is set equal to 1. This maximizes the calculated present worth of the averted dose.

Average Concentration from Corrective Action (Conc)

Equation 2 was designed for the cleanup of soils and structures where cleanup is over a discrete area and the resulting contamination levels are static through time. Application of this equation to a groundwater context requires some assumptions regarding the average residual activity concentration of the exposure media over the duration of potential exposure. The proposed control boundary covers an area of 9.7 square miles and groundwater concentrations over this area vary from background to higher levels over different areas and different groundwater. There are 18 identified domestic well permits in the proposed boundary that represent the permitted points of access to and use of groundwater (see Appendix 4.4-A Future Water Use demand Basis of Estimate).

The base-case predictive uranium groundwater transport models were used to identify the predicted groundwater uranium concentrations at each well location for each of the four affected water bearing units (alluvial aquifer and Upper, Middle, and Lower Chinle sandstone units) over the 1,000-year simulation period. Predicted groundwater uranium concentrations for each of the 19 well locations, in each water bearing unit, for each year of the simulation period were identified and basic statistics (maximum, minimum, average) for those data were developed for each well location (Table 1). Attachment 1 to this technical memorandum includes the electronic files containing the predicted groundwater uranium concentrations for each of the 19 well locations, in each water bearing unit, for each year of the simulation period.

It should be noted that this is a highly conservative analysis as the 19 wells cannot be replaced at the end of their functional life, estimated to be approximately 50 to 70 years, due to the 2018 State of New Mexico Order prohibiting new or replacement wells in this area.

Derived Concentration Limit Goal ($DCGL_W$)

The derived concentration guideline level (DCGL) is a radionuclide-specific surface or volume residual radioactivity level related to a concentration, dose or risk criterion. A reasonable target dose criterion to use to establish a derived concentration guideline levels for uranium in groundwater attributable to the GRP is 25 mrem/year per 10 CFR 20.1402. Based on the annual radiation dose calculated for a resident gardener using a nominal uranium concentration in groundwater of 1 Bq/L, 3.41 mrem/yr (Appendix 3.5-A of the ACL application), the derived concentration guideline level ($DCGL_w$) would be as follows:

$$DCGL_W = Conc.* \frac{Dose\ Criterion}{Calculated\ Dose} = 1\ Bq/L\ * \frac{25\ mrem/yr}{3.41\ mrem/yr}$$

$$= \ 7.3 \frac{Bq}{L}\ or\ 0.29\ mg/L\ or\ 198\ pCi/L$$

Discount Rate (r)

Per Section N.1.1. of Appendix N to NUREG-1757, Vol.2, Revision 1 (NRC, 2006), a discount rate (r) of 7 percent should be used for doses averted within the first 100 years. For doses averted beyond 100 years, a 3 percent discount rate should be used.

Decay Constant (λ)

The radiological decay constant (λ) for uranium can be calculated assuming uranium isotopes are found in their natural abundance and with uranium-238 in secular equilibrium with is progeny, uranium-234. The isotope uranium-235 is an insignificant contribution to the averted dose calculation. This is a reasonable assumption given the small amount of uranium-235 typically present is less than one percent of the total natural uranium present at natural abundance. Radiological decay of natural uranium is governed by the half-life of uranium-238 of 4.5 billion years, which results in an insignificant decay correction over a 1000-year time period.

Duration of Collective Dose (N)

The duration over which collective dose (N) is calculated is assumed to be 1,000 years.

Calculation of Benefit

Apply the following inputs to Equation 2.

P_D x A = 57 persons (site critical group)
0.025 = rem/person
F =1 (100% effective remediation)
Conc = See Table 2
$DCGL_w$ = See Table 2
r = 7% for the first 100 years, 3% thereafter through 1,000 years
λ = see Table 3

Table 3 summarizes the calculated present worth of that avoided dose for each alternative.
These calculations indicate that the total averted dose for 1,000-year exposure ranges from 11.63 person-rem (Alternative 1) to 113.86 person-rem (Alternative 3). The calculated benefit derived from these averted doses range from $72,660 (Alternative 1) to $711,648 (Alternative 3).

Summary and Conclusions

This analysis indicates that the benefit of collective averted dose (B_{AD}) for implementing the groundwater action alternatives addressed in the ACL Application range on the order of $70,000 to $700,000. Further, the relationship of the B_{AD} to the affected population size (P_D x A) and the average concentration within the proposed control boundary (average exposure concentration: Conc) is directly proportional and linear (e.g., a doubling of the Conc. value or the affected population size results in a doubling of the B_{AD} value).

Therefore, the several conservative assumptions applied in this analysis (full exposure pathways for all well permit locations despite all having municipal water supply and no documented groundwater use, replacement of wells after functional life of existing wells end is not permissible) ensures that this estimate of the monetary value of avoided future hypothetical dose is reasonable and conservative. In addition, this analysis assumes the potential exposures occur for the entire 1,000-year compliance period. It should be noted that application of the maximum well concentration values for each alternative from Table 1 to the calculations in Table 2 and Table 3 would result in a maximum benefit of averted doses for a 1,000-year exposure period of less than $700,000. The actual future dose from groundwater above background is projected to be zero, as there is no current human ingestion of groundwater and HMC will own and control all future access to and use of groundwater.

References

NRC, 2003. U.S. Nuclear Regulatory Commission. Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act of 1978. NUREG-1620, Revision 1. June 2003.

NRC, 2006. U.S. Nuclear Regulatory Commission. Consolidated Decommissioning Guidance Characterization, Survey, and Determination of Radiological Criteria. NUREG-1757, Vol. 2, Rev.1. September 2006.

NRC, 2017. U.S. Nuclear Regulatory Commission. Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission, Draft for Comment. NUREG/BR-0058. April, 2017.

NRC, 2022. U.S. Nuclear Regulatory Commission. Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy Final Report. NUREG-1530, Rev. 1. February 2022.

TABLES

Table 1 Predicted Uranium Concentrations at Permitted Wells (mg/L)

Permit /Alternative	[1]Maximum	[1]Minimum	[1]Average
B_00132			
Alternative 1	0.0638	0.0638	0.0638
Alternative 2	0.0638	0.0638	0.0638
Alternative 3	0.0638	0.0638	0.0638
B_00147			
Alternative 1	0.0682	0.0196	0.0393
Alternative 2	0.0764	0.0196	0.0407
Alternative 3	0.0981	0.0196	0.0433
B_00163			
Alternative 1	0.183791	0.02	0.03856404
Alternative 2	2.49399	0.02	0.1695743
Alternative 3	3.03476	0.02	0.20232005
B_00164			
Alternative 1	0.149276	0.0200218	0.04627487
Alternative 2	4.05367	0.0200219	0.19602029
Alternative 3	5.0948	0.0200222	0.24324947
B_00165			
Alternative 1	0.60969	0.0200137	0.06508527
Alternative 2	5.28321	0.0200137	0.29271465
Alternative 3	7.71316	0.0200138	0.39668738
B_00166			
Alternative 1	0.189732	0.02	0.03891257
Alternative 2	2.65607	0.02	0.17484404
Alternative 3	3.25869	0.02	0.20890552
B_00178			
Alternative 1	0.0535	0.0357	0.0451
Alternative 2	0.6789	0.0390	0.1445
Alternative 3	6.3325	0.0388	1.3288
B_00180			
Alternative 1	0.217423	0.0200047	0.04601106
Alternative 2	4.88124	0.0200047	0.38658258
Alternative 3	7.65393	0.0200048	0.8244831
B_00203			
Alternative 1	0.283177	0.0178968	0.0424004
Alternative 2	0.619591	0.0178968	0.14246708
Alternative 3	8.25828	0.0178967	1.59695849
B_00220			
Alternative 1	0.074839	0.0199823	0.03751854
Alternative 2	0.303467	0.0199823	0.06118199
Alternative 3	1.64532	0.0199823	0.22934289
B_00221			
Alternative 1	0.595008	0.0200082	0.05149527
Alternative 2	5.0931	0.0200082	0.32964494
Alternative 3	8.05211	0.0200084	0.52907268
B_00251			
Alternative 1	0.66184	0.020012	0.06042985
Alternative 2	5.02218	0.020012	0.29185917
Alternative 3	7.17772	0.0200124	0.40409144
B_00279			
Alternative 1	0.20937	0.02	0.04567045
Alternative 2	2.2713	0.02	0.23670217
Alternative 3	6.24946	0.02	0.6754745
B_00352			
Alternative 1	0.047019	0.034902	0.03907818
Alternative 2	0.655351	0.034902	0.13448703
Alternative 3	6.29057	0.0348816	1.27468041
B_00415			
Alternative 1	0.279091	0.005	0.054673
Alternative 2	2.53608	0.005	0.283473
Alternative 3	4.17769	0.005	0.528098
B_00435			
Alternative 1	0.115828	0.0197227	0.06102088
Alternative 2	0.096812	0.0197232	0.04953308
Alternative 3	0.057598	0.0197367	0.03031923
B_00458			
Alternative 1	0.376064	0.0199932	0.09918805
Alternative 2	0.631205	0.0199932	0.19979632
Alternative 3	1.37343	0.0199932	0.27664432
B_00583			
Alternative 1	0.305349	0.0199957	0.06984815
Alternative 2	2.3009	0.0199957	0.29279154
Alternative 3	3.41457	0.0199958	0.4122144
B_00676			
Alternative 1	0.076478	0.0199742	0.03815727
Alternative 2	0.141265	0.0199742	0.04432956
Alternative 3	1.36498	0.0199741	0.17022635
B_00698			
Alternative 1	0.038559	0.021271	0.02939022
Alternative 2	0.035987	0.0212686	0.02802488
Alternative 3	0.035465	0.0212641	0.02785335

	Maximum (mg/L)	Minimum (mg/L)	Average (mg/L)
Alternative 1	0.662	0.005	0.050
Alternative 2	5.283	0.005	0.172
Alternative 3	8.258	0.005	0.491

[1]Predicted uranium concentrations from bounding-case model for 1,000-year simulation

Table 2 Maximum Predicted POE Concentrations, Doses, and Risks

Radionuclide	Alternative 1	Alternative 2	Alternative 3
Maximum Base-Case Modeled POE Concentrations			
CONC (mg/L)	0.0502	0.1720	0.4914
Uranium* (pCI/L)	33.97	116.42	332.69
Thorium-230 (pCI/L)	background	background	background
Combined Radium-226+228 (pCI/L)	background	background	background
Dose at base-case concentrations from all pathways (mrem/yr)			
Dose at Unit Concentration	3.41		
Dose from Uranium (person-mrem/yr)	4.28	14.68	41.96
Total person-rem/yr	0.004	0.015	0.042
30-year Lifetime Dose	0.129	0.441	1.259
30-year Lifetime Risk (Morbidity)	3.24E-05	1.11E-04	3.18E-04
30-year Lifetime Risk (Mortality)	2.12E-05	7.27E-05	2.08E-04
Natural Uranium			
$DCGL_W$ (pCi/L)	198.2		
Conc/$DCGL_W$	0.171	0.587	1.678

* converted from mg/L 677 pCi/mg

† Based on Alluvial Groundwater Background of 0.16 mg/L

††27 pCi/Bq

Table 3 Calculation of Present Worth and Benefit of Averted Dose from Natural Uranium

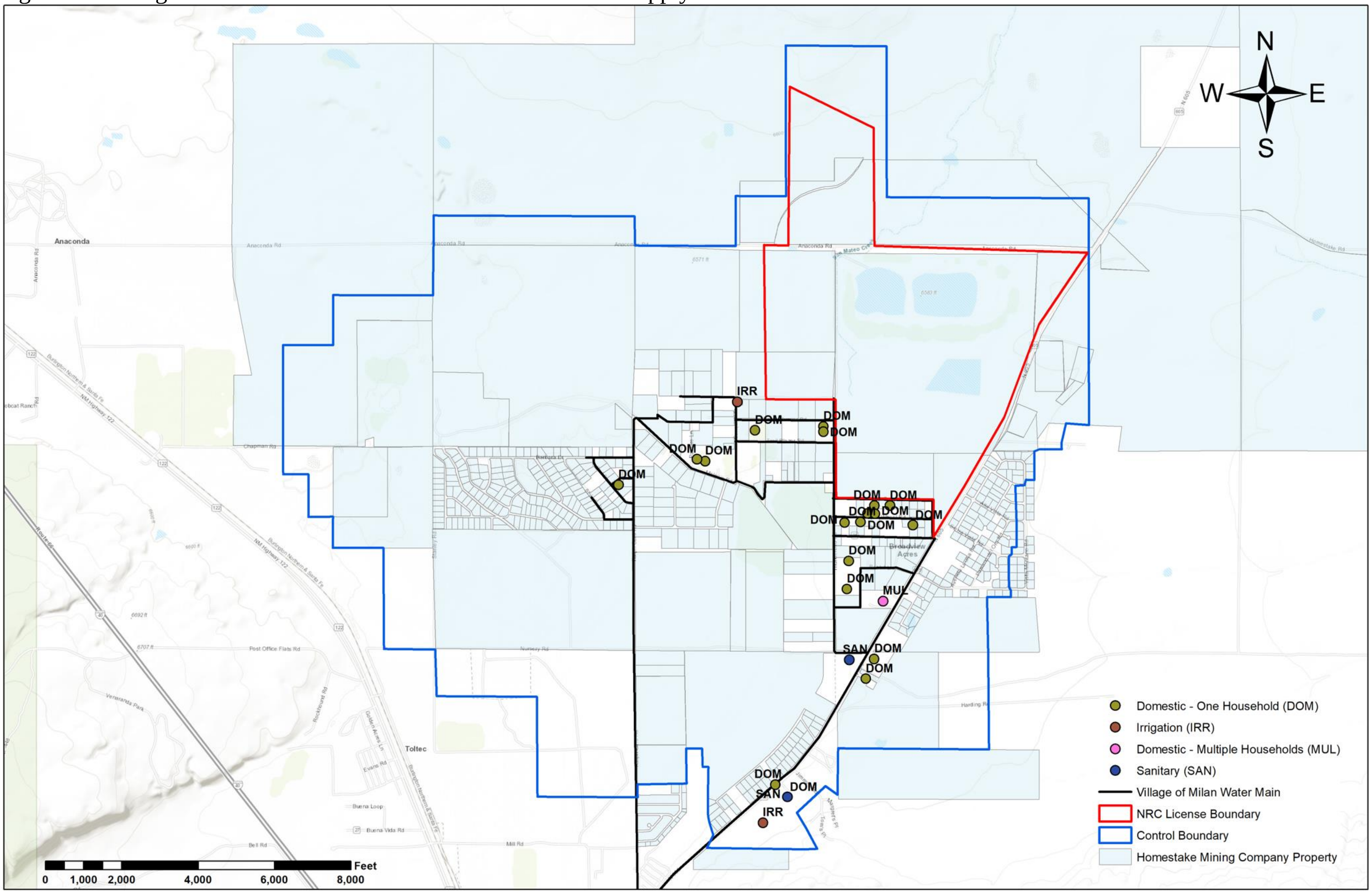
First 100 years						
Alternative	**$PW(AD_{collective})$ (person-rem)**	**$1 - e^{-(\lambda+r)N} /(\lambda+r)$**	**$e^{-(\lambda+r)N}$ N = 100 yrs**	**$(\lambda + r)$ r = 0.07**	**λ (1/yr)**	**1/2 life (T) (yrs)**
Alternative 1	3.49	14.3	9.12E-04	0.070000	1.540E-10	4,500,000,000
Alternative 2	11.95					
Alternative 3	34.14					
Remaining 900 years						
Alternative	**$PW(AD_{collective})$ (person-rem)**	**$1 - e^{-(\lambda+r)N} /(\lambda+r)$**	**$e^{-(\lambda+r)N}$ N = 900 yrs**	**$(\lambda + r)$ r = 0.03**		
Alternative 1	8.14	33.3	1.88E-12	0.030000		
Alternative 2	27.90					
Alternative 3	79.73					

Total for 1,000 years		
Alternative 1	11.63	**Total person-rem**
Alternative 2	39.84	**Total person-rem**
Alternative 3	113.86	**Total person-rem**

Benefit of Averted Dose			
		$ 6,250	**(V_{AD}) $/person-rem (2022 dollars)**
B_{AD} Alt 1	**$ 72,660**		
B_{AD} Alt 2	**$ 249,030**		
B_{AD} Alt 3	**$ 711,648**		
	$ 638,988	**Difference between benefit of Alternative 1 vs Alternative 3**	
	$ 462,618	**Difference between benefit of Alternative 2 vs Alternative 3**	

FIGURES

Figure 1 Existing Well Permit Locations and Alternative Water Supply Lines



ATTACHMENT 1
Electronic Files: Predicted Concentrations at Permitted Wells