APPENDIX A
PHOTOGRAPHS

PHOTO 1. View of retort building and retort tailings deposit

PHOTO 2. View of retort building from the North

PHOTO 3. View of the retort. Note collapsed roof.

PHOTO 4. View of south end of retort building.

PHOTO 5. View of mercury condenser equipment

PHOTO 6. View of retort. Note collapsed roof

PHOTO 7. View of retort equipment looking toward north end of retort building

PHOTO 8. View of retort tailings deposit

PHOTO 9. View of north end of retort building

PHOTO 10. View of fallen retort stack.

PHOTO 11. View of south end of retort.

PHOTO 12. View of retort tailings dump chute tunnel beneath retort building

PHOTO 13. View of retort tailings deposit

PHOTO 14. View of retort tailings deposit from the west. Note establishment of vegetation

PHOTO 15. View of retort tailings and retort building from the south.

PHOTO 16. View of retort tailings deposits downstream from the retort building

PHOTO 17. View of retort building

PHOTO 18. View of Mine Spring

PHOTO 19. View of vertical shaft area.

APPENDIX I
ECOLOGICAL RISK ASSESSMENT REPORT

Final Ecological Risk Assessment, Pine Mountain Mine, Tonto National Forest, Mesa Ranger District, Maricopa County, Arizona

Prepared for

MACTEC Engineering and Consulting, Inc.

Prepared by

SWCA Environmental Consultants

January 19, 2005

Final
Ecological Risk Assessment, Pine Mountain Mine
Tonto National Forest – Mesa Ranger District
Maricopa County, Arizona

Prepared for:

MACTEC Engineering and Consulting, Inc.
3630 East Wier Avenue
Phoenix, Arizona 85040

Prepared by:

Bill Leibfried, Matt Lauretta, and Kevin Serrato

SWCA Environmental Consultants
114 N. San Francisco St., Suite 100
Flagstaff, Arizona 86001
(928) 774-5500
www.swca.com

Project # 7596-091

January 19, 2005

TABLE OF CONTENTS

Executive Summary iii

INTRODUCTION 1
Background 1

METHODS 4

BIOLOGICAL RESULTS 4
Vegetation 4
Fauna 6

ENVIRONMENTAL CONTAMINANTS REPORT 7

LITERATURE REVIEW 8
Mercury Introduction into Biotic Systems 9
Affect of Mercury on Fish 9
Terrestrial Pathways for Mercury Contamination 10

DISCUSSION 10

CONCLUSIONS 11

LITERATURE CITED 12

List of Figures

1. Project location in relation to the Phoenix metro area..... 2

2. Location of Pine Mountain project..... 3

List of Tables

1. Plants Identified from the Pine Mountain Site 5

2. Federal and State Special Status Plants Possibly Found at Pine Mountain Mine Site 5

3. Federal and state listings of special status animals potentially occurring on or near the Pine Mountain Mine site, and the Gila topminnow, proposed for reintroduction in Sycamore Creek..... 6

4. Summary Table of MACTEC (2004b) Results for Mercury and Arsenic Species Found at the Pine Mountain Mine Site Reported in Micrograms per Gram (ug/g)..... 7

EXECUTIVE SUMMARY

This ecological risk assessment is part of an Engineering Evaluation/Cost Analysis (EE/CA) requested by the U.S. Forest Service pertaining to the environmental condition of the Pine Mountain Mine site. The Pine Mountain Mine is an abandoned mercury mine located in Maricopa County, Arizona on the Tonto National Forest. Mining activities ended in 1983 leaving a small open pit, underground workings with associated shafts and adits, several concrete foundations, processed retort tailings, minor debris from houses, vehicles, pipes, mine rail, and the mill retort building. Pine Mountain Mine lies in an unnamed drainage basin that flows into the ephemeral East Fork of Sycamore Creek, which eventually drains into the mainstem of Sycamore Creek. The U.S. Forest Service as the responsible land management agency in this area is requesting a risk assessment of possible impacts from past mining activities on flora and fauna, particularly special status species, in the vicinity of the site. This assessment focuses on the potential risk to the federally endangered Gila topminnow (*Poeciliopsis occidentalis occidentalis*) that has been proposed for introduction into Sycamore Creek. At this time no firm plans for introduction of Gila topminnow exist.

MACTEC Engineering and Consulting, Inc. sampled the area around Pine Mountain Mine for the presence of heavy metals and determined mercury and arsenic to be constituents of potential concern. Arsenic levels detected were elevated in most of the sample sites around Pine Mountain Mine, including background soils. The frequency and distribution of these high levels indicate that arsenic levels are not related to the historical mining activity and the area is naturally high in arsenic; therefore, potential arsenic contamination was removed from further investigation. Details of the MACTEC sampling are found in MACTEC (2004a,b).

The ecological risk assessment suggests that the conditions required for the formation of toxic species of mercury are not present at the Pine Mountain Mine site. Also, it was determined that mercury concentrations found at Pine Mountain Mine are not at levels that would significantly affect the flora and fauna in the area.

If it were introduced into Sycamore Creek, the Gila topminnow would not be significantly affected by runoff from the Pine Mountain Mine site. Most of the mercury species found at site are not toxic. The toxic form of mercury that is present was found in low concentrations. Similar concentrations have been shown not to have a significant effect on the fathead minnow, a surrogate species for the Gila topminnow.

INTRODUCTION

The Pine Mountain Mine is an abandoned mercury mine located in Maricopa County, Arizona, within the Tonto National Forest on the Mesa Ranger District (Figures 1 and 2). Cinnabar was the primary ore mined at the site, and mercury was extracted from the ore at a retort facility located near the mine. The United States Forest Service (USFS), the responsible land management agency for the site, requested that an Engineering Evaluation/Cost Analysis (EE/CA) be prepared to assess the condition of the property. MACTEC Engineering and Consulting, Inc. (MACTEC) was retained by the mine owner to conduct this analysis (MACTEC 2004a). Pine Mountain Mine lies in an unnamed drainage basin, which is dry except for periods of intense precipitation. Storm runoff from this drainage flows into the ephemeral East Fork of Sycamore Creek and eventually to Sycamore Creek. Elevation of the Pine Mountain Mine site is approximately 5,200 feet above mean sea level.

SWCA Environmental Consultants (SWCA) was contracted by MACTEC to provide an ecological risk assessment to determine the biological effects of current site conditions. (MACTEC 2004a). SWCA sent biologists to the Pine Mountain Mine site to evaluate the existing biological conditions, including habitat for special status species that may occur in the area. As part of this assessment, SWCA conducted a literature review of the effects of mercury on flora and fauna. The results of the site visit and the literature review were used to assess the risks posed by current mine site conditions on the target special status species.

The endangered Gila topminnow (*Poeciliopsis occidentalis occidentalis*) is the primary species of concern for this risk assessment, although this fish species is not currently present in the Sycamore Creek drainage. Historical occurrence of topminnow in Sycamore Creek is uncertain due to lack of data on fish distribution. The possibility of stocking Gila topminnow in the creek was raised in the recovery plan for the species (Weedman 1998) and has been discussed by the Arizona Game and Fish Department. However, the USFS has no plans for introduction of the topminnow into Sycamore Creek at this time (Masters 2004).

BACKGROUND

In 1967, the Gila topminnow was designated endangered by the U.S. Fish and Wildlife Service (USFWS) (USFWS 2004). The Gila topminnow is a small fish that is generally tan to olive colored, with darker dorsal coloration and a light to whitish ventral coloration (Minckley 1973). A dark band is present along both sides of the body. Scales on the dorsum are darkly outlined and extend as black speckles to the upper belly and pre-pectoral area. The dorsal profile is slightly curved and the body is somewhat elongated. The caudal fin is rounded to almost square. The fins are characterized by rays that are outlined with melanophores and lack dark spots.

The native range included Arizona, New Mexico, and Mexico (Minckley 1973). The Gila topminnow habitat is found in lowland springs, streams, and margins of large rivers of deserts and grasslands, specifically the Gila drainage basin (USFWS 2004). It prefers warm, shallow water with large algal mats and debris covering sandy substrates. The Gila topminnow can withstand a range of temperatures and salinities (BISON 2004). Their diet consists of organic detritus, vegetation, aquatic invertebrates, and crustaceans. They also give birth to live young usually in cooler waters. Once considered one of the most widespread species in the southwest,

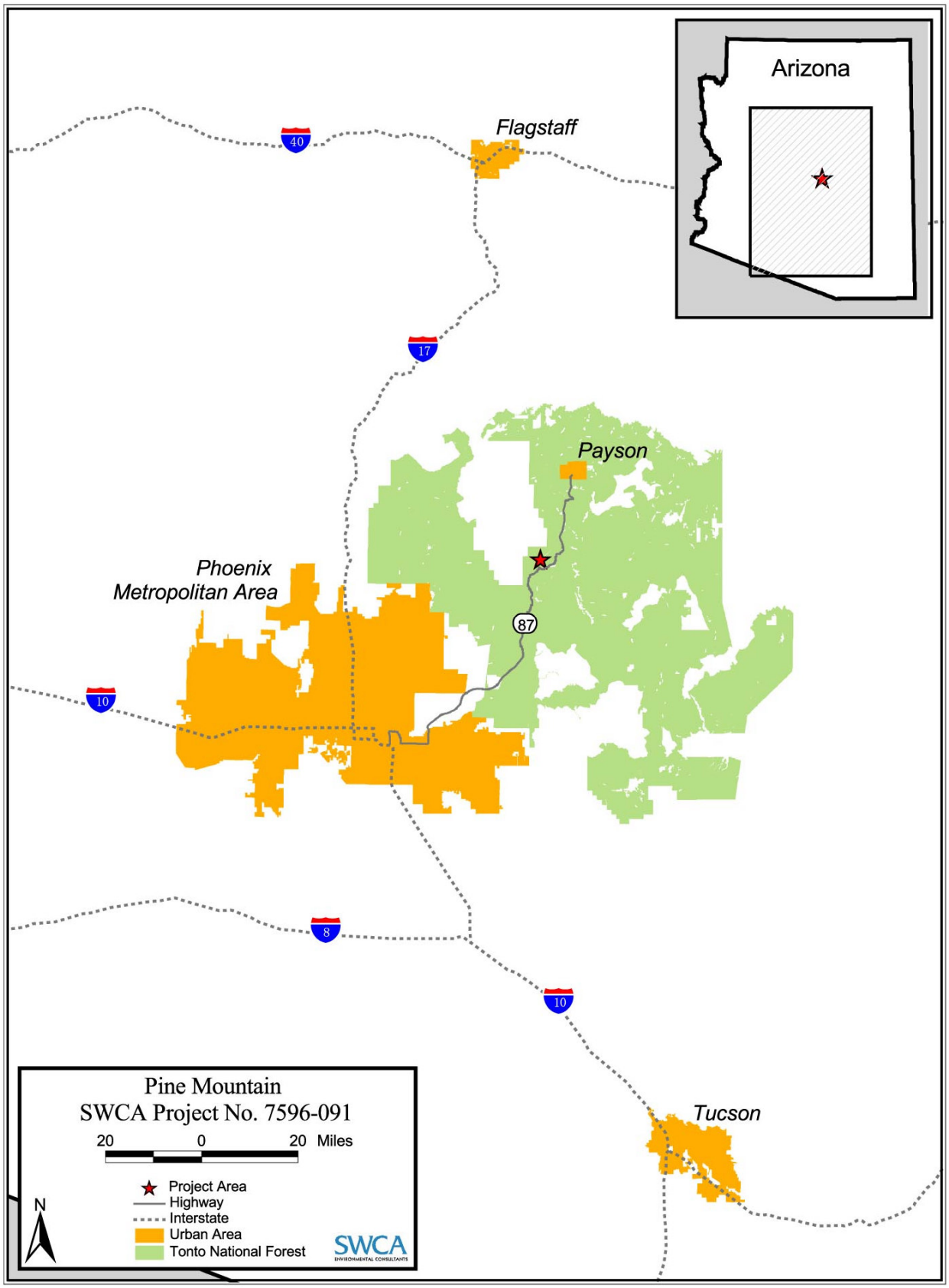

Figure 1. Project location in relation to the Phoenix metro area.

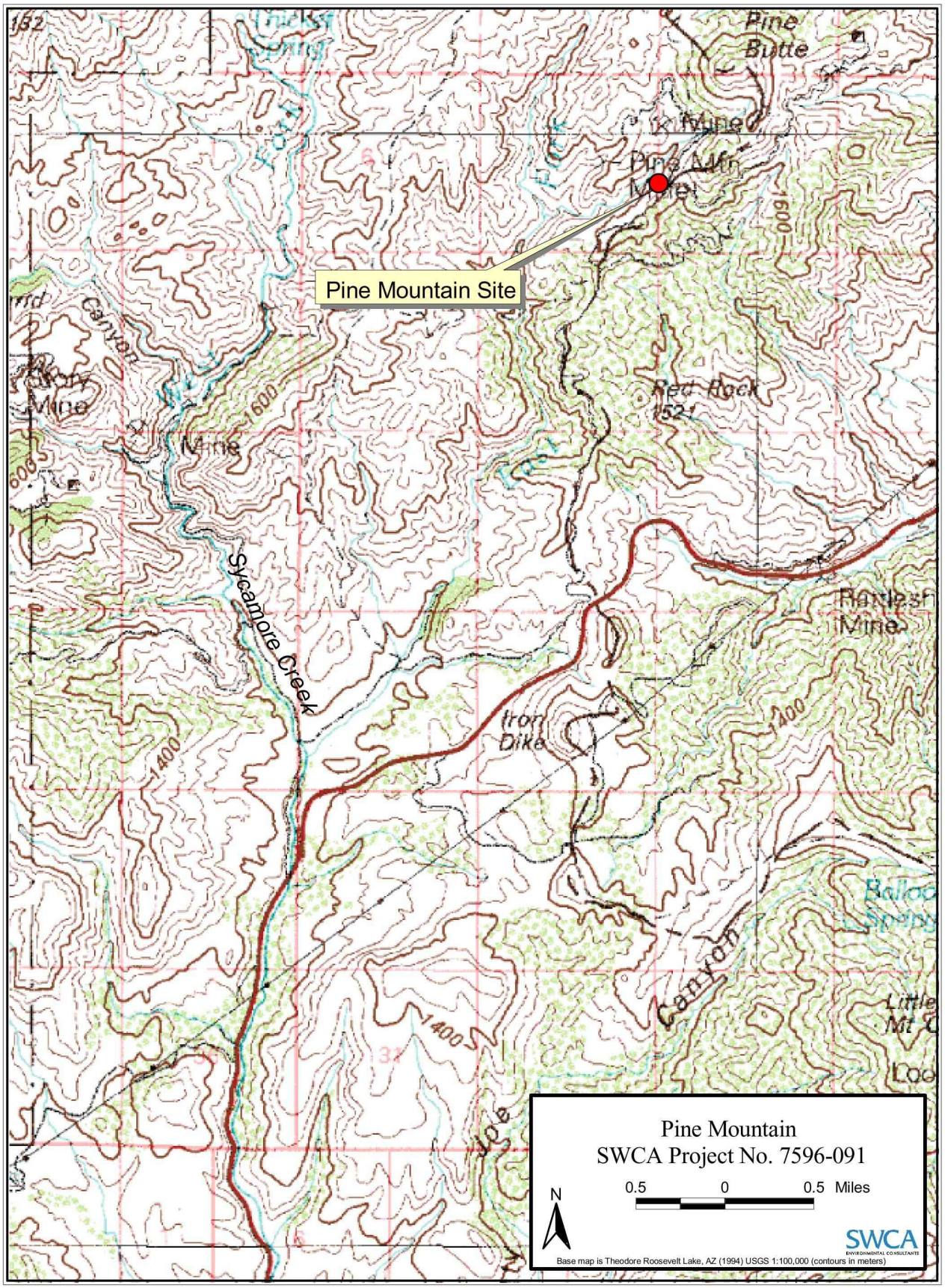

Figure 2. Location of Pine Mountain project.

populations began to decline after the 1940s (USFWS 2004). Despite efforts of recovery, including many attempts at reintroduction into suitable habitat, Gila topminnow populations continue to decline. This decline has been attributed to the loss of habitat and the introduction of non-native species, in particular the western mosquito fish (*Gambusia affinis*), which directly preys on the topminnow (USFWS 2004).

METHODS

To assess the biological resources of the Pine Mountain Mine site, SWCA first contacted Tonto National Forest staff and the USFWS to identify the flora and fauna and special status species that are likely to occur in the area. SWCA also consulted the Arizona Game and Fish Department Heritage Data Management System. The species data provided by the Forest Service reflects the most recent surveying efforts conducted in 2003 and covers the entire Tonto National Forest, an area encompassing almost three million acres. SWCA narrowed the list of potentially affected species, first to include only the Mesa Ranger District, and then by comparing the species' required habitat to the habitats available in and around Pine Mountain Mine Site. On February 25, 2004, a botanist with SWCA visited the mine site to identify the habitats present, assess their general quality, and identify the plant species present. Based on data gathered during the site visit, SWCA biologists were able to assess the likelihood of any special status species occurring on or near the site. SWCA also conducted a literature review to provide background information on the effects of possible constituents of concern (COC), notably mercury, on the biological environment.

MACTEC Engineering and Consulting, Inc. provided environmental quality data used in the determination of the potential environmental risk of contamination from the mine site. Their testing was designed to provide data on heavy metal concentrations in the soil, streambed sediments, and surface and ground water quality of the study site. The resulting data and environmental contaminants report are found in MACTEC's EE/CA (MACTEC 2004b).

SWCA used the data provided by MACTEC in conjunction with the information gathered during the site visit and literature review to assess the potential risk of mine-related contaminants to biological resources in the area, particularly special status species.

BIOLOGICAL RESULTS

VEGETATION

Vegetation observed at the Pine Mountain Mine site is representative of the higher elevation chaparral community that commonly occurs in Arizona (Brown 1994). Plants recorded at the site are listed in Table 1.

After consulting the Tonto National Forest Sensitive Species list and Arizona Game and Fish Department Heritage Data Management System, it was determined that suitable habitat exists on or near the Pine Mountain Mine site for the special status plant listed in Table 2.

Table 1. Plants Identified from the Pine Mountain Site

Common Name	Scientific Name
Palmer's agave	*Agave palmeri*
manzanita	*Arctostaphylos pungens*
three-awn grass	*Aristida purpurea*
big sagebrush	*Artemisia tridentata*
California brickellbush	*Brickellia californica*
ceanothus	*Ceanothus greggii*
hedgehog cactus	*Echinocereus engelmannii*
yerba santa	*Eriodictyon angustifolium*
buckwheat	*Eriogonum* sp.
filaree, heron's bill	*Erodium cicutarium*
silktassel	*Garrya wrightii*
broom snakeweed	*Gutierrezia sarothrae*
one-seeded juniper	*Juniperus monosperma*
beargrass	*Nolina microcarpa*
prickly pear	*Opuntia engelmannii*
spruce	*Picea pungens*
shrub live oak	*Quercus turbinella*
buckthorn	*Rhamnus californica*
smooth sumac	*Rhus glabra*
groundsel	*Senecio* sp.
globemallow	*Sphaeralcea* sp.
alkali sacaton	*Sporobolus airoides*
jewelflower	*Streptanthus arizonicus*
graythorn	*Ziziphus obtusifolia*

Table 2. Federal and State Special Status Plants Possibly Found at Pine Mountain Mine Site

Common Name	Scientific Name	Status	Habitat
Arizona agave	*Agave arizonica*	E, HS	Mesas and slopes in Interior Chaparral and Desert Grassland communities at elevations from 3,000 to 6,000 feet.
Arizona hedgehog	*Echinocereus triglochidiatus* var. *arizonicus*	E, HS	Interior Chaparral and Madrean Evergreen Woodland communities at elevations 3,300 to 5,700 feet.
Tonto basin agave	*Agave delamateri*	SC, S, HS	Benches and mesa tops, in cobbly and gravelly, deep and well-drained soils at elevations from 2,300 to 5,100 feet
Arizona giant sedge	*Carex ultra*	S	Riparian areas and moist soil at 2,000 to 6,000 feet.
Mogollon fleabane	*Erigeron anchana*	S	Rock crevices in pinyon-juniper, chaparral, and pine-oak forests from 3,500 to 7,000 feet.

E – Listed as Endangered under the Endangered Species Act (ESA): imminent jeopardy of extinction.
SC – Species of Concern: may be of concern to USFWS, but does not have official status (currently all former C2 species).
S – Forest Service Sensitive: taxa occurring on national forests in Arizona that are considered sensitive by the Regional Forester.
HS – Highly Safeguarded: plants whose prospects for survival in Arizona are in jeopardy or which are in danger of extinction.

FAUNA

Field surveys conducted by the Tonto National Forest in September 2003 found 291 species of animals in the Mesa Ranger District. Of those 291 species, 17 were classified as special status species in the recently updated version of special status species on the Tonto National Forest (March 28, 2003; see Table 3).

Table 3. Federal and State Listings of Special Status Species Potentially Occurring on or near the Pine Mountain Mine Site, and the Gila Topminnow, Proposed for Reintroduction in Sycamore Creek

Common Name	Scientific Name	Status
Amphibians (1)		
lowland leopard frog	*Rana yavapaiensis*	SC, S, WC
Reptiles (4)		
Sonoran desert tortoise	*Gopherus agassizii*	SC, S, WC
Arizona night lizard	*Xantusia vigilis arizonae*	S
Maricopa leafnose snake	*Phyllorhynchus browni lucidus*	S
Mexican garter snake	*Thamnophis eques megalops*	SC, S, WC
Fish (1)		
Gila topminnow	*Poeciliopsis occidentalis occidentalis*	E, WSCA
Birds (7)		
bald eagle	*Haliaeetus leucocephalus*	T, WSCA, MIS
Mexican spotted owl	*Strix occidentalis lucida*	T, WSCA
western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	C, S, WSCA,
peregrine falcon	*Falco peregrinus anatum*	SC, S, WSCA
common black hawk	*Buteogallus anthracinus*	S, WSCA, MIS
northern goshawk	*Accipiter gentilis*	SC, S, WSCA, MIS
Arizona Bell's vireo	*Vireo bellii*	S, MIS
Mammals (4)		
California leaf-nosed bat	*Microtus californicus*	SC, WSCA, HP
spotted bat	*Euderma maculatum*	SC, WSCA, HP
Allen's big-eared bat	*Idionycteris phyllotis*	SC, HP
desert bighorn sheep	*Ovis canadensis mexicana*	S

E – Listed as Endangered under the ESA: imminent jeopardy of extinction.
T – Listed as Threatened under the ESA: imminent jeopardy of becoming Endangered.
C – Candidate: USFWS has sufficient information on biological vulnerability and threats to support proposals to list as Endangered or Threatened under the ESA.
SC –Species of Concern: may be of concern to USFWS, but does not have official status (currently all former C2 species).
S – Forest Service Sensitive: taxa occurring on national forests in Arizona that are considered sensitive by the Regional Forester.
MIS – Management Indicator Species for Tonto National Forest
WSCA – Wildlife of Special Concern in Arizona
HP – High Priority bat species according to Bat Conservation International (BCI)

Only three of the species, the bald eagle, Mexican spotted owl, and the Gila topminnow, are federally listed as either Threatened or Endangered under the Endangered Species Act (ESA). The SWCA site survey indicated that habitat for these three species is not present in the vicinity of the Pine Mountain Mine site. The Gila topminnow is not currently found in Sycamore Creek and no plans for introduction are in place at this time (Masters 2004). A major impediment to successful introduction of Gila topminnow is the presence of non-native fishes in Sycamore Creek that prey and compete with native fishes.

Of the remaining 14 species, only two, California leaf-nosed bat and the Allen's big-eared bat, have potential habitat on the Pine Mountain Mine site. The northern goshawk has potential for foraging in the area, but nesting is unlikely due to this species' preference for large coniferous forest.

ENVIRONMENTAL CONTAMINANTS REPORT

MACTEC's soil and sediment data did not show significant contamination levels at the Pine Mountain Mine site (MACTEC 2004b). Of all the heavy metals tested, only mercury and arsenic were found at levels exceeding Arizona Department of Environmental Quality (ADEQ) standards, and only at a few testing sites (MACTEC 2004b). A summation of findings for extractable mercury and for arsenic, as well as the pertinent Arizona state standards, is shown in Table 4. State standards are expressed as Residential Soil Remediation Levels (RSRLs) and Non-Residential Soil Remediation Levels (NRSRLs). ADEQ's provisional RSRLs and NRSRLs and those stipulated in Arizona law (A.A.C. R18-7-205) are provided at the bottom of the table. No data were obtained on water quality due to a lack of precipitation and runoff in amounts that would make testing feasible. A complete set of data and a thorough explanation of the findings can be found in MACTEC's EE/CA (MACTEC 2004b).

Table 4. Summary Table of MACTEC (2004b) Results for Mercury and Arsenic Species Found at the Pine Mountain Mine Site Reported in Micrograms per Gram (ug/g)

	Mercury Speciation			Arsenic Speciation		
Sample I.D.	**Total Mercury (ug/g)**	**Extractable Inorganic (ug/g)**	**Extractable Organic (ug/g)**	**Total Arsenic (ug/g)**	**As III (ug/g)**	**As Inorganic (ug/g)**
Area DSS						
DSS-2-S	65.099	1.668	0.002	22.726	0.186	22.54
DSS-3-S	NA	NA	NA	22.912	0.078	22.834
DSS-4-S	63.483	0.566	0.006	NA	NA	NA
Area RT						
RT-1-S	250.976	2.169	0.003	92.385	0.974	91.411
RT-2-S	593.162	33.542	0.009	NA	NA	NA
RT-9-S	151.486	19.994	0.007	NA	NA	NA
RT-12-S	NA	NA	NA	58.386	0.447	57.939
RT-13-S	NA	NA	NA	39.455	0.427	39.028
RT-17-S	36.854	0.621	0.001	NA	NA	NA
RT-20-S	NA	NA	NA	29.762	0.076	29.686

Table 4. Summary Table of MACTEC (2004b) Results for Mercury and Arsenic Species Found at the Pine Mountain Mine Site Reported in Micrograms per Gram (ug/g), continued.

Sample I.D.	Mercury Speciation			Arsenic Speciation		
	Total Mercury (ug/g)	Extractable Inorganic (ug/g)	Extractable Organic (ug/g)	Total Arsenic (ug/g)	As III (ug/g)	As Inorganic (ug/g)
Area RB						
RB-6-S	3,583.489	83.820	0.032	83.011	0.337	82.674
RB-7-S	7,105.270	755.812	0.686	74.971	1.213	73.758
Area USS						
USS-1-S	0.308	0.008	0.0007	33.347	0.22	33.127
Area BS						
BS-6-S	0.769	0.008	0.002	NA	NA	NA
BS-20-S	0.381	0.007	0.003	NA	NA	NA
BS-9-S	0.915	0.008	0.001	241.292	0.224	241.068
BS-9-1	2.799	0.265	0.002	421.696	0.668	421.028
BS-29-S	NA	NA	NA	82.188	0.148	82.04
BS-35-S	NA	NA	NA	339.675	0.108	339.567
BS-17-S	NA	NA	NA	77.135	0.112	77.023
BS-3-S	0.127	0.008	0.0004	NA	NA	NA
Area PF						
PF-40-S	16.365	1.431	0.008	26.809	0.055	26.754
PF-33-S	3.299	0.008	0.003	NA	NA	NA
PF-31-S	41.246	3.934	0.012	11.315	0.059	11.256
PF-22-S	NA	NA	NA	17.964	0.054	17.91
PF-14-S	3.022	0.234	0.004	NA	NA	NA
PF-35-S	NA	NA	NA	15.595	0.035	15.56
Arizona State RSRL *	NL	23	6.5	10	10	10
ADEQ provisional RSRL	NL	23	6.1	10	10	10
Arizona State NRSRL**	NL	510	68	10	10	10
ADEQ provisional NRSRL	NL	307	62	10	10	10

* Residential Soil Remediation Level (RSRL) at Appendix A of A.A.C. R18-7-205.
** Non-Residential Soil Remediation Level (NRSRL) at Appendix A of A.A.C. R18-7-205.

LITERATURE REVIEW

SWCA conducted a literature review to provide background information on the effects of constituents of potential concern (COPC) on the biological environment. Results from MACTEC soil and sediment sampling indicated that there were only two COPCs: mercury and arsenic. The reported arsenic levels originated from natural sources (MACTEC 2004b), leaving mercury as the only COPC for the risk assessment.

Information gleaned from the literature review on the potential ecological effects of various forms of mercury is summarized below.

MERCURY INTRODUCTION INTO BIOTIC SYSTEMS

Areas rich in inorganic mercury ores, particularly cinnabar, have elevated environmental concentrations of mercury that may be exposed during surface mining. (Harnly et al. 1997). These concentrations can further be increased by exposure from mining operations. Most of the mercury found in the environment is in inorganic forms, all of which have some toxic properties, but toxicity is generally minor compared to that of organic mercury species (Fitzgerald and Clarkson 1991, Zillioux et al. 1993, both cited in Carroll 2000). Methyl mercury (MeHg) is the most abundant form of organic mercury and is formed from a variety of biotic and abiotic processes. The most significant contribution results as a metabolic byproduct of sulfur-reducing bacteria (Carroll 2000). Sulfur-reducing bacteria are widespread in anaerobic bottom sediments and are found in colder, less turbid water.

Since streams are usually well oxygenated, sulfur-reducing bacteria are limited in those environments and, if present, are typically found in the anoxic channel bottoms and backwater habitats of larger streams (Gilmore and Henry 1991, Marilainen 1995, Watras et al. 1995, all cited in Carroll 2000). The rate at which sulfur-reducing bacteria produce MeHg is affected by temperature and pH. An increase in temperature or a decrease in pH has been shown to increase the rate of methylation (Carroll 2000).

MeHg generally enters the food chain through direct consumption of water or biota, though non-dietary routes, such as uptake through the absorbing epithelium, occurs with less frequency (Burger et al. 2001). Unlike other heavy metals that diffuse out as readily as they diffuse in, mercury that has entered an organism reacts with cellular components like the lipid storage often found around the cellular membranes and is efficiently retained within the microorganism (Carroll 2000). Organisms contaminated with mercury are often consumed by predators, who in turn absorb that mercury at higher concentrations from their prey species. Studies have shown that efficiency of transfer often increases with subsequent trophic levels. This efficiency increases the ability of the predator to retain MeHg.

AFFECT OF MERCURY ON FISH

Fish species of concern for this risk assessment is limited to the federally listed Gila topminnow. Studies on the effects of mercury contamination on the Gila topminnow are unavailable. Therefore, a surrogate species, the fathead minnow, was identified to complete the analysis. The fathead minnow is the closest relative to the Gila topminnow that has been studied for the effects of mercury contamination.

The affect of MeHg on fathead minnows is not fully understood, but recent studies by Hammerschmidt et al. (2002) have documented reproductive impacts. The accumulation of MeHg in fish comes primarily from diet, though there is documentation of maternal transfer of small amounts from mother to progeny (Hammerschmidt et al. 2002).

Hammerschmidt et al. (2002) found that dietary MeHg did not reduce the growth and survival of adult fathead minnows. They did, however, find a positive correlation in spawning males who showed an increase in size. No correlation was established between MeHg and adult mortality.

MeHg in the food chain was found to reduce gonadal development and the daily reproductive effort of female fathead minnows, reducing overall reproductive success. The researchers found that exposure to MeHg can interfere with the production of estrogen, thereby reducing the number, size, and quality of eggs. It was also shown that dietary MeHg affected the overall reproductive performance of adult fathead minnows, but maternally transferred MeHg did not measurably affect embryos and larva.

Hammerschmidt et al. (2002) attempted to account for a criticism of many laboratory studies concerning the effects of MeHg use unrealistically high concentrations. In an attempt to correct for this bias they tried to mimic conditions found in natural waters, thus creating a control concentration of 0.06ug MeHg, a low concentration of 0.88ug MeHg, a medium concentration of 4.11ug MeHg, and a high concentration of 8.46ug MeHg.

TERRESTRIAL PATHWAYS FOR MERCURY CONTAMINATION

The U.S. Environmental Protection Agency (EPA) reviewed literature published on the uptake of mercury into terrestrial systems (EPA 1997). They reported that mercury uptake by plants from soil is possible, but studies have indicated that concentrations are not significant (Schuster 1991, Lindqvist et al. 1991, both cited in EPA 1997). Atmospheric uptake of mercury by terrestrial plants accounts for a portion of mercury contamination, but there is debate over which is the more significant source, soil or air (Cappon 1981, 1987, both in EPA 1997). Regardless, findings indicate that mercury concentration in plants is low despite the source of contamination (EPA 1997). Terrestrial pathways through plants are therefore not a significant source of mercury introduction into the environment (EPA 197).

DISCUSSION

The key factor in determining the concentration of mercury in biota is the MeHg concentration in water, which is controlled by the relative efficiency of the methylation and demethylation processes (Morel 1998). These processes are facilitated by sulfur-reducing bacteria and require anoxic soils typically found in standing water. The lack of consistent precipitation and standing water at the Pine Mountain Mine site likely prevents the formation of these anoxic soils on-site. While a series of heavy precipitation events, such as those that occur during the summer monsoon season, could conceivably wash trace amounts of inorganic mercury downstream into Sycamore Creek, and anoxic soils might be present so as to allow methylation to occur, this is not likely since stream flows provide a continuous supply of oxygenated water. It is possible that small patches of anoxic soil might be found in the deep stream channel or in isolated, ephemeral pools that can form when water recedes following flooding events.

The highest concentration of MeHg found by MACTEC in the area around Pine Mountain Mine was 0.686 ug/g MeHg at a site near the retort building (see Table 4). This concentration is well below the ADEQ provisional standards (6.1 ug/g for RSRL and 62 ug/g for NRSRL) and is less than the experimental low concentration (0.87 ug/g) established by Hammerschmidt et al. (2002) to observe effects of naturally occurring mercury levels on fathead minnows. Hammerschmidt's experimental low concentration resulted in a reduction of spawning success by about 5% when compared to the control concentration, but was not lethal to any minnows. Since the highest

concentrations measured at the Pine Mountain Mine site are less than the experimental low concentrations in the Hammerschmidt study, it can be concluded that the potential impacts to minnow reproduction from MeHg reaching Sycamore Creek would be negligible. No other impact to fish in the stream is likely.

The amounts and form of mercury measured in vegetated areas were representative of background levels. For this reason, and because research has demonstrated low levels of mercury uptake in plants from soil and air sources, it is unlikely that vegetation, including special status plants, on-site or in the surrounding area is being adversely affected by mercury contamination at the mine.

The potential for mercury contamination in the three special status animal species is nonexistent to negligible. The California leaf-nosed bat and Allen's big-eared bat feed on insects that feed on vegetation; however, the level of MeHg in the soil around Pine Mountain Mine was well below ADEQ provisional standards, and the uptake of mercury by the local vegetation is expected to be negligible. No other potential for adverse effects on special status species is likely.

Arsenic levels at Pine Mountain Mine site are believed to be naturally occurring (MACTEC 1994b); therefore, the local flora and fauna, including special status species, in the area are not being adversely affected by arsenic contamination the resulted from past mining activities at the site.

CONCLUSIONS

The environmental risk to the flora and fauna, including special status species, in the vicinity of the Pine Mountain Mine site from mineral contamination at the site is negligible. The environmental risk to the Gila topminnow, if it were introduced into Sycamore Creek, would also be negligible.

LITERATURE CITED

BISON (Biota Information System of New Mexico). 2004. Species Accounts: Gila topminnow. New Mexico Department of Game and Fish. Online at: http://fwie.fw.vt.edu/states/nmex_main/species/010565.htm (accessed June 2004).

Brown, D.E. 1994. Biotic communities southwestern United States and northwestern Mexico. University of Utah Press, Salt Lake City.

Burger, J., K.F. Gaines, S. Boring, W.L. Stephens Jr., J. Snodgrass, and M. Gochfeld. 2000. Mercury and selenium in fish from the Savannah River: Species, trophic level, and locational differences. Environmental Research 87(2):108–118.

Cappon, C.J. 1981. Mercury and selenium content and chemical form in vegetable crops grown on sludge-amended soil. Archives of Environmental Contaminates and Toxicology 10:673–689.

Cappon, C. J. 1987. Uptake and speciation of mercury and selenium in vegetable crops grown on compost-treated soil. Water, Air, and Soil Pollution 34:353–361.

Carroll, R.W.H, J.J. Warwick, K.J. Heim, J.C. Bonzongo, J.R. Miller, and W.B. Lyons. 2000. Simulation of mercury transport and fate in the Carson River, Nevada. Ecological Modelling 125:255–278.

Fitzgerald, M.F., and T.W. Clarkson. 1991. Mercury and monomethyl-mercury: present and future concerns, global atmospheric change and human health. Environmental Health Perspectives 96:159–166.

Gilmour, C.C., and E.A. Henry. 1991. Mercury methylation in aquatic systems affected by acid deposition. Environmental Pollution 71:131.

Hammerschmidt, C.R., M.B. Sandheinrich, J.G. Wiener, and R.G. Rada. 2002. Effects of dietary methylmercury on reproduction of fathead minnows. Environmental Science and Technology 36:877–883.

Harnly, M., S. Seidel, P. Rojas, R. Fornes, P. Flessel, D. Smith, R. Kreutzer, and L. Goldman. 1997. Biological monitoring for mercury within a community with soil and fish contamination. Environmental Health Perspectives 105:424–429.

Kelly, C.A., J.W.M. Rudd, and M. H. Holoka. 2003. Effect of pH on mercury uptake by an aquatic bacterium: Implications for Hg cycling. Environmental Science and Technology 37:2941–2946.

Lindqvist, O., K. Johansson, M. Aastrup, A. Andersson, L. Bringmark, G. Hovsenius, L. Hakanson, A. Iverfeldt, M. Meili, and B. Timm. 1991. Mercury in the Swedish Environment - Recent Research on causes, consequences and corrective methods. Water, Air, and Soil Pollution 55:(all chapters).

MACTEC Engineering and Consulting, Inc. 2004a. Work plan engineering evaluation/cost analysis, Pine Mountain Mine, Tonto National Forest – Mesa Ranger District, Maricopa County, Arizona. United Nuclear Corporation, Gallup New Mexico.

MACTEC Engineering and Consulting, Inc. 2004b. Draft Final Report EE/CA Pine Mountain Mine, Tonto National Forest – Mesa Ranger District, Maricopa County, Arizona. United Nuclear Corporation, Gallup New Mexico.

Martilainen, T. 1995. Involvement of bacteria in methylmercury formation in anaerobic lake waters. Water, Air, and Soil Pollution 80(1-4):757–764.

Masters, J. (U.S. Forest Service Wildlife Biologist). 2004. Personal communication with K. Serrato of SWCA Environmental Consultants, Flagstaff, Arizona. June 24.

Minckley, W.L. 1973. Fishes of Arizona. Sims Printing Company, Inc., Phoenix, Arizona.

Morel, F.M.M., A.M.L. Kraepiel, and M. Amyot. 1998. The chemical cycle and bioaccumulation of mercury. Annual Review of Ecological Systems 29:543–566.

Schuster, E. 1991. The behavior of mercury in the soil with special emphasis on complexation and adsorption processes: A review of the literature. Water, Air, and Soil Pollution. 56:667–680.

U.S. Environmental Protection Agency. 1997. Mercury study report to Congress: Volume III, Fate and transport of mercury in the Environment. Office of Quality Planning and Standards, and Office of Research and Development. Online at: http://www.epa.gov/ttn/oarpg/t3/reports/volume3.pdf (accessed June 2004).

U.S. Fish and Wildlife Service. 2004. NatureServe Explorer Species Report: *Poeciliopsis occidentalis* - (Baird and Girard, 1853), Gila Topminnow. Online at: http://www.natureserve.org/explorer/servlet/NatureServe?searchName=Poeciliopsis+occidentalis (accessed June 2004).

U.S. Forest Service. 2004. Tonto National Forest. USDA Forest Service. Online at: http://www.fs.fed.us/r3/tonto/ (accessed June 2004).

Watras, C.J., N.S. Bloom, S.A. Class, K.A. Morrison, C.C. Gilmore, and S.R. Craig. 1995. Methylmercury production in the anoxic hypolimnion of a climatic seepage lake. Water, Air, and Soil Pollution 80(1-4)735–745.

Weedman, D.A. 1998. Gila topminnow, *Poeciliopsis occidentalis occidentalis*, revised recovery plan. Prepared by Arizona Game and Fish Department, Phoenix, Arizona, for Region 2, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

World Wide Web (WWW) 2004. Real estate. Payson Neighborhood. Online at: http://realestate.yahoo.com/re/neighborhood/search.html?csz=Payson%2CAZ (accessed June 2004).

Zillioux, E.J., D.B. Porcella, and J.M. Benoit. 1993. Mercury cycling and effects in freshwater wetland ecosystems. Environmental Toxic Chemicals 12:2245–2264.

APPENDIX J
REMOVAL ACTION ALTERNATIVE COST DETAILS

TABLE J-1
COST DETAIL
RT/DSS AOI REMOVAL ACTION OPTIONS

	UNITS	COST / UNIT	TOTAL COST
OPTION 1 - NO ACTION	**0**	**0.00**	**0.00**
OPTION 2 - IN-PLACE CLOSURE			
Improve access road to Site	1	60,000.00	60,000.00
Install 0.5 mile haul road to base of retort tailings pile	1	52,000.00	52,000.00
Move 2,000 c.y of tailings to re-grade area	2000	25.00	50,000.00
Confirmatory sampling and analysis	1	10,000.00	10,000.00
Grade retort tailings to 3:1 slope and install channel	1	440,000.00	440,000.00
Place approximately 5,000 cy of cover on tailings	5000	25.00	125,000.00
Vegetate covered tailings, borrow area, and haul road	1	20,000.00	20,000.00
ARAR Costs	1	25,000.00	25,000.00
Project management and reporting (10% of costs)	0.1	782,000.00	78,200.00
Long-term O&M (assume $5,000 per year over 30 years)	1	332,194.00	332,194.00
Base Cost Estimate			1,192,394.00
Plus 30% contingency	1.3	1,192,394.00	1,550,112.20
Option 2 Cost Range			**$1,192,394 - $1,550,112**
OPTION 3 - ON-SITE CONSOLIDATION			
Improve access road to Site	1	60,000.00	60,000.00
Install 0.5 mile haul road to base of retort tailings pile	1	52,000.00	52,000.00
Move 9,000 c.y of material to consolidation cell	9000	25.00	225,000.00
Confirmatory soil sampling and analysis	1	15,000.00	15,000.00
Reclaim/revegetate consolidation cell, road, and borrow	1	20,000.00	20,000.00
ARAR Costs	1	25,000.00	25,000.00
Project management and reporting (10% of costs)	0.1	397,000.00	39,700.00
Base Cost Estimate			436,700.00
Plus 30% contingency	1.3	436,700.00	567,710.00
Option 3 Cost Range			**$436,700 - $567,710**
OPTION 4 - OFF-SITE DISPOSAL			
Improve access road to Site	1	60,000.00	60,000.00
Install/reclaim 0.5 mile haul road to base of retort tailings	1	60,000.00	60,000.00
Confirmatory soil sampling and analysis	1	15,000.00	15,000.00
Move 9,000 c.y of material to transfer area	9000	25.00	225,000.00
Transport and dispose 13,500 tons at landfill	13500	60.00	810,000.00
ARAR Costs	1	25,000.00	25,000.00
Project management and reporting (10% of costs)	0.1	1,195,000.00	119,500.00
Base Cost Estimate			1,314,500.00
Plus 30% contingency	1.3	1,314,500.00	1,708,850.00
Option 4 Cost Range			**$1,314,700 - $1,708,850**

TABLE J-2
COST DETAIL
RB AOI REMOVAL ACTION OPTIONS

	UNITS	COST / UNIT	TOTAL COST
OPTION 1 - NO ACTION	**0**	**0.00**	**0.00**
OPTION 2 - LIMITED ACCESS			**$30,000 - $50,000**
OPTION 3 - LIMITED ACCESS AND SOIL REMOVAL			
Additional Investigation	1	10,000.00	10,000.00
Soil removal and hazwaste disposal (drums)	10	800.00	8,000.00
Confirmatory soil sampling and analysis	1	5,000.00	5,000.00
Project management and reporting (20% of costs)	0.2	18,000.00	3,600.00
Base Cost Estimate			26,600.00
Plus 50% contingency	1.5	26,600.00	39,900.00
Access Limitations Cost Range			$30,000 - $50,000
Option 3 Cost Range			**$56,600 - $89,900**
OPTION 4 - RB DEMOLITION TO SLAB AND LIMITED SOIL REMOVAL			
Improve access road to site	1	60,000.00	60,000.00
Demolish retort building to slab	1	200,000.00	200,000.00
Additional Investigation	1	10,000.00	10,000.00
Soil removal and hazwaste disposal (600 tons)	600	350.00	210,000.00
Confirmatory soil sampling and analysis	1	5,000.00	5,000.00
ARAR Costs	1	15,000.00	15,000.00
Project management and reporting (10% of costs)	0.1	500,000.00	50,000.00
Base Cost Estimate			550,000.00
Plus 50% contingency	1.5	550,000.00	825,000.00
Option 4 Cost Range			**$550,000 - $825,000**
OPTION 5 - RB DEMOLITION AND LIMITED SOIL REMOVAL			
Improve access road to site	1	60,000.00	60,000.00
Demolish retort building to slab	1	200,000.00	200,000.00
Additional Investigation	1	10,000.00	10,000.00
Soil removal and hazwaste disposal (600 tons)	900	350.00	315,000.00
Confirmatory soil sampling and analysis	1	5,000.00	5,000.00
ARAR Costs	1	15,000.00	15,000.00
Project management and reporting (10% of costs)	0.1	605,000.00	60,500.00
Base Cost Estimate			665,500.00
Plus 50% contingency	1.5	665,500.00	998,250.00
Option 5 Cost Range			**$665,500 -$998,250**

TABLE J-3
COST DETAIL
REMOVAL ACTION ALTERNATIVE OPTIONS

REMOVAL ACTION ALTERNATIVE	COST RANGE
ALTERNATIVE 1 - NO ACTION	**$0.00**
ALTERNATIVE 2 - ACCESS LIMITATIONS	**$30,000 - $50,000**
ALTERNATIVE 3	
No Action Area RT/DSS	$0.00
Area RB Option 3 Cost Range (Table J-2)	$56,600 - $89,900
Alternative 3 Cost Range	**$56,600 - $89,900**
ALTERNATIVE 4	
No Action Area RT/DSS	**$0.00**
Area RB Option 4 Cost Range (Table J-2)	$550,000 - $825,000
Alternative 4 Cost Range	**$550,000 - $825,000**
ALTERNATIVE 5	
No Action Area RT/DSS	$0.00
Area RB Option 5 Cost Range (Table J-2)	$665,500 -$998,250
Alternative 5 Cost Range	**$665,500 -$998,250**
ALTERNATIVE 6	
Area RT/DSS Option 2 Cost Range (Table J-1)	$1,192,394 - $1,550,112
RB Option 5 Cost Range minus access road (Table J-2)	$599,500 - $899,250
Alternative 6 Cost Range	**$1,791,894 -$2,449,362**
ALTERNATIVE 7	
Area RT/DSS Option 3 Cost Range (Table J-1)	$436,700 - $567,710
RB Option 5 Cost Range minus access road (Table J-2)	$599,500 - $899,250
Alternative 7 Cost Range	**$1,036,200 -$1,466,960**
ALTERNATIVE 8	
Area RT/DSS Option 4 Cost Range (Table J-1)	$1,314,700 - $1,708,850
RB Option 5 Cost Range minus access road (Table J-2)	$599,500 - $899,250
Alternative 8 Cost Range	**$1,914,200 - $2608,100**