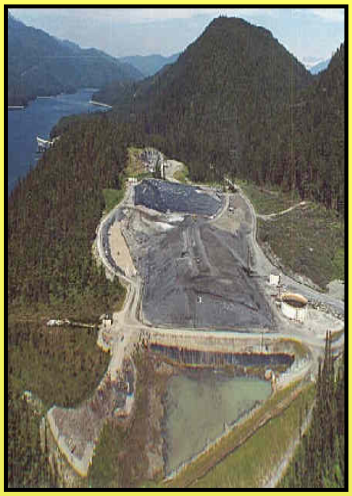

Comparison of Predicted and Actual Water Quality at Hardrock Mines

The reliability of predictions in Environmental Impact Statements

Buka Environmental

Kuipers & Associates

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Front Cover: Left- Tailings impoundment at the Greens Creek Mine in Alaska USA (Courtesy of David Chambers). Center – Heap leach pad at Marigold Mine in Nevada (Ann Maest). Right – Waste rock dump and open pit at Beal Mountain Mine in Montana (Jim Kuipers). Back cover: Open pit at the Golden Sunlight Mine, Montana (Courtesy of Jeff Barber).

This publication was made possible by EARTHWORKS in Washington, DC, USA with the support of the Wilburforce Foundation of Seattle, Washington, USA. EARTHWORKS is a non-profit organization dedicated to protecting communities and the environment from the destructive impacts of mineral development in the U.S. and worldwide. The organization's mission is to work with communities and grassroots groups to reform government policies, improve corporate practices, influence investment decisions and encourage responsible materials sourcing and consumption.

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PREFACE

The overall purpose of this study is to examine the reliability of pre-mining water quality predictions at hard rock mining operations in the United States. To our knowledge, no effort has previously been made to systematically compare predicted and actual water quality for mines in the U.S. or elsewhere. Environmental Impact Statements (EISs) and similar documents under federal and state law are the single publicly available source of water quality predictions for hard rock mines, and thus they were chosen as the information foundation for conducting the research. In designing the project, we decided to look broadly at as many mines as possible rather than concentrate on an in-depth analysis of a few mines. This approach – which shows general trends and can more easily be extrapolated to the larger set of hard rock mines – will provide the most useful results for mine regulators, which are the principal intended audience for the study. More in-depth studies of individual mines would be a natural next step for continuing investigations.

As part of the study, requests were made to federal and state agencies to provide National Environmental Policy Act (NEPA) documents and information on operational water quality. The effort required to obtain the documents and information, although initially expected to be onerous, was more arduous and protracted than we imagined. We were surprised to find that no single repository exists for NEPA documents, although the Environmental Protection Agency does have most EISs on microfiche. Technical reports associated with EISs were extremely difficult to obtain. Similarly, the availability of operational water quality information was uneven, ranging from disorganized paper-only copies in some states to user-friendly electronic information in others. The authors are grateful to the many agencies that did provide documents and water quality data. One of the most important recommendations in the report is that operational water quality data should be made available to the public in a transparent and easily accessible manner.

The report finds that adverse impacts to water quality are common at mine sites, and they are most often caused by failed mitigation. We recommend that a more in-depth study of the effectiveness of common mitigation measures be undertaken. Another important cause of water quality impacts is errors in geochemical and hydrologic characterization of the mined materials and the mine site area. The companion report (*Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State- of-the-Art)* makes a number of concrete suggestions for improving characterization and predictions.

This report also identifies inherent risk factors that may lead to water quality impacts. Although all mines require carefully executed mitigation measures, mines close to water resources with high acid drainage or contaminant leaching potential need special attention in terms of mitigation and characterization. Adopting protective mitigation and characterization approaches, as recommended here and in the companion report, will help prevent unacceptable water quality impacts, decrease long-term costs, and help instill public trust in the industry. This report is ultimately intended to advance the practice of science, engineering and regulation related to water quality prediction, the recognition of risk, and the application of effective mitigation to hardrock mines. The authors encourage ongoing cooperative efforts with regulators, scientists and engineers, non-governmental organizations, and industry to further the work begun in this study.

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September 2006

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Ann S. Maest, PhD, of Buka Environmental, is an aqueous geochemist specializing in the fate and transport of contaminants in natural waters. As a consultant, she has designed, conducted, and managed hydrogeochemistry and modeling studies and worked on independent monitoring and community capacity building projects at numerous mining sites in the U.S. and Latin America. At the U.S. Geological Survey, she conducted research on metal and metalloid speciation in surface water and groundwater. Dr. Maest has published articles on the fate and transport of metals in natural waters and served on national and international committees related to hardrock mining and sustainable development. She holds a PhD in geochemistry and water resources from Princeton University and an undergraduate degree in geology from Boston University.

Kimberley A. MacHardy, Associate Geoscientist with Kuipers & Associates, has a Master's Degree in Geosciences from Montana Tech of The University of Montana. Ms. MacHardy has worked on mine sites in Montana, and mine impacted sites in Nevada, prepared sampling and analysis plans, and coordinated, conducted, and directed field sampling programs. She has worked for two years on the Good Neighbor Agreement for the Stillwater Mine in Montana, where she conducted monthly sampling for water quality parameters and river flows on the Stillwater River, as well as periodic macroinvertebrate and nutrient sampling on both the Stillwater and East Boulder Rivers in Montana.

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Project advice, input and internal peer review were provided by Tom Myers, PhD, hydrogeologist, Dave Chambers, PhD, Center for Science in Public Participation and Glenn Miller, PhD, biochemist, of the University of Nevada-Reno. Technical review and editing was performed by Peggy Utesch and Sarah Zuzulock.

Various versions of the database, report and sections of the report were sent to state and federal regulators and industry consultants for review and comment. Because of the nature of this report, with many site specific examples, it was difficult to obtain peer review for every example and for the report as a whole. Reviewers included regulators from EPA, BLM and the Forest Service as well as industry consultants, and included Stephen Hoffman and Patricia McGrath of the EPA; and Jack Mozingo (Black & Veatch) and Andrew Robertson (Robertson Geoconsultants). The authors take sole responsibility for the contents of the report and will consider additional review comments for future publication or additional efforts derived from this report.

The involvement of all the reviewers lead to substantial improvements to this report and are greatly appreciated

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LIST OF ACRONYMS

ABA	Acid Base Accounting
ACE	Army Corp of Engineers
ADEQ	Arizona Department of Environmental Quality
Ag	Silver
AGP	Acid Generating Potential
Al	Aluminum
ANP	Acid Neutralizing Potential
APP	Arizona Aquifer Protection Permit
As	Arsenic
B	Boron
BADCT	Best Available Demonstrated Control Technology
Be	Beryllium
bgs	below ground surface
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BMP	Best Management Practices
Ca	Calcium
CA WET	California Waste Extraction Test
Cd	Cadmium
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Cl	Chloride
CN	Cyanide
COE	Army Corp of Engineers
Cr	Chromium
Cu	Copper
DI	Deionized Water
DL-SX	Dump Leach Solvent Extraction
EA	Environmental Assessment
EA/EIR	Environmental Assessment /Environmental Impact Report
ECHO	EPA's Enforcement History and Online Database
EECA	Engineering Evaluation /Cost Analysis
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EIS/EIR	Environmental Impact Statement /Environmental Impact Report
EPA	Environmental Protection Agency
EP Toxicity	Extraction Procedure Toxicity Test
F	Flotation
F	Fluoride
Fe	Iron
FG	Flotation and Gravity
FOIA	Freedom of Information Act
FONSI	Finding of No Significant Impact
Ft	Feet
gpm	gallons per minute
g/l	grams per liter
Hg	Mercury

HL	Heap Leach
HCT	Humidity Cell Tests
LAD	Land Application Discharge
MAS/MILS	Mineral Availability System /Mineral Industry Locater System
MCL/SMCL	Maximum Contaminant Level/Secondary Maximum Contaminant Level
MDEQ	Montana Department of Environmental Quality
mg/l	milligrams per liter
μg/l	micrograms per liter
msl	mean sea level
MEP	Multiple Extraction Procedure
MEPA	Montana Environmental Protection Act
Mg	Magnesium
Mn	Manganese
MWMP	Metric Water Mobility Procedure
N	Nitrogen
NAG	Net Acid Generating
NCV	Net Carbonate Value
NDEP	Nevada Department of Environmental Protection
NEPA	National Environmental Policy Act
NGOs	Non-Governmental Organizations
NH_4	Ammonia
Ni	Nickel
NNP	Net Neutralizing Potential
NO_3	Nitrate
NP	Neutralizing Potential
NP/AP	Neutralizing Potential/Acid Potential
NPDES	National Pollution Discharge Elimination System
OP	Open Pit
P	Phosphorous
PAG	Potentially Acid-Generating
Pb	Lead
PER	Preliminary Environmental Review
PLS	Pregnant Leach Solution
PGM	Platinum Group Minerals
ppm	parts per million
ROD	Record of Decision
RWD	Report of Waste Discharge
RWQCB	Regional Water Quality Control Board
S	Smelter
Sb	Antimony
SDWA	Safe Drinking Water Act
Se	Selenium
SEIS	Supplemental Environmental Impact Statement
SO_4	Sulfate
SPLP	Synthetic Precipitation Leaching Procedure
SSRE	Sequential Saturated Rolling Extraction
STLC	Soluble Threshold Limit Concentration
SWCB	State Water Control Board
SX/EW	Solvent Extraction Electrowinning
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
Tl	Thallium

t/kt	tons per kiloton
TTLC	Total Threshold Limit Concentrations
UG	Underground
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
VL	Vat Leach
WAD	Weak Acid Dissociable
WQ	Water Quality
Zn	Zinc

EXECUTIVE SUMMARY

INTRODUCTION AND APPROACH

This study reviews the history and accuracy of water quality predictions in Environmental Impact Statements (EISs) for major hardrock mines in the United States. It does so by:

- identifying major hardrock metals mines in the United States and determining which major mines had EISs
- gathering and evaluating water quality prediction information from EISs
- selecting a representative subset of mines with EISs for in-depth study
- examining actual water quality information for the case study mines, and
- comparing actual water quality to the predictions made in EISs.

Based on the results of the evaluations conducted, an analysis was performed to identify the most common causes of water quality impact and prediction failures. In addition, an analysis was conducted to determine if there were inherent risk factors at mines that may predispose an operation to having water quality problems. Conclusions are provided about the effectiveness of the underlying scientific and engineering principles used to make water quality predictions in EISs. Finally, recommendations are made for regulatory, scientific and engineering approaches that would improve the reliability of water quality predictions at hardrock mine sites.

The National Environmental Policy Act (NEPA), enacted in 1969, was the first environmental statute in the United States and forms the foundation of a comprehensive national policy for environmental decision making. NEPA requires federal agencies to take a “hard look” at the environmental impacts of each proposed project to ensure the necessary mitigation or other measures are employed to meet federal and state regulations and other applicable requirements. Under NEPA, when a new mine is permitted, agencies have a duty to disclose underlying scientific data and rationale supporting the conclusions and assumptions in an EIS.

NEPA requires federal agencies proposing major actions that may substantially affect the quality of the human environment to prepare a detailed Environmental Impact Statement (EIS). A “major action” includes actions approved by permit or other regulatory action. If the agency finds that the project *may* have a significant impact on the environment, then it must prepare an EIS. As part of the EIS process, hardrock mines operating on federal lands or otherwise subject to NEPA are required to estimate impacts to the environment, including direct impacts to water quality and indirect impacts that occur later in time but are still reasonably foreseeable. The NEPA analysis process calls for performing original research, if necessary, and reasonable scientifically supported forecasting and speculation. A wide array of scientific approaches has been used to predict water quality that could result at mine sites, and many different engineering techniques were applied to mitigate these potential impacts. The primary subject of this report is the effectiveness of water quality predictions and mitigation that were applied over the past 30 years as a part of the EIS process at hardrock mines in the United States.

IDENTIFICATION OF MAJOR AND NEPA-ELIGIBLE HARD ROCK MINES

Major Hardrock Metal Mines in the United States

Hardrock metal mines in the United States produce gold, silver, copper, molybdenum, lead, zinc and platinum group metals from open pit and underground mining operations. For the purpose of this study, “major” mines were defined as: those that have a disturbance area of over 100 acres and a financial assurance amount of over $250,000; have a financial assurance of $1,000,000 alone (regardless of acreage); or have a production history (since 1975) of greater than 100,000 ounces of gold, 100,000,000 pounds of copper or the monetary value equivalent in another metal. Using those criteria, 183 major hardrock metal mines were identified as having operated since 1975.
The major hardrock mines are located in fourteen states (Alaska, Arizona, California, Colorado, Idaho, Michigan, Montana, Nevada, New Mexico, South Carolina, South Dakota, Utah, Washington and Wisconsin), with the vast

majority (178 of 183) located in western states. Nevada has the greatest number of major mines of any state, with 74 (40%) of the total major mines. Sixty-three percent (63%) of the mines produce gold and/or silver, 16% produce copper, 4% produce copper and molybdenum, 2% produce molybdenum only, 4% produce lead and zinc, and 1% produce platinum group metals (percentages add to greater than 100 because some mines produce multiple commodities).

Seventy-two percent (72%) of the major hardrock mines in the U.S. that have operated since 1975 are open pit mines, while 15% are underground. Sixty-six percent (66%) of the major hardrock mines use cyanide heap or vat leaching, 24% use flotation or gravity processing and 12% process ore by acid dump leaching and solvent extraction/ electrowinning.

Forty-five percent (45%) of the 183 major hardrock mines in operation since 1975 are still operating, and 49% have closed. Only one new major hardrock mine is currently (as of 2005) in construction, and seven others are in various stages of permitting. After the NEPA processes were completed, development proposals were withdrawn for four of the major hardrock mines identified in this study.

Major Hardrock Metal Mines Subject to NEPA

Mines located on federal land administered by the Bureau of Land Management or the Forest Service are subject to the requirements of NEPA. Also subject to NEPA regulations are certain National Pollution Discharge Elimination System (NPDES) permits issued by the Environmental Protection Agency, certain 404 Wetlands permits from the Army Corp of Engineers, and mines located on Native American trust lands administered by the Bureau of Indian Affairs (BIA). In addition, some states (California, Montana, Washington and Wisconsin) have a state-mandated process that is equivalent to NEPA.

NEPA requires environmental analysis of federal actions. As it has evolved, an EIS is required for any "major federal action significantly affecting the quality of the human environment," and an Environmental Assessment (EA) is required for lesser actions. EAs do not require public comment; the results of an EA can determine whether the action is significant, which will trigger an EIS, but usually the EA is performed in lieu of an EIS.

Of the 183 major modern-era hardrock mines identified, 137 (75%) had federal actions that triggered NEPA analysis. Ninety-three (68%) were located on BLM land, thirty-four (25%) on Forest Service land, and nine (7%) on both BLM and Forest Service land. Disturbance of wetlands triggered NEPA analysis at five (4%) of the mines, requiring a 404 wetlands permits from the Corp of Engineers (COE); a discharge into a water of the United States was the only NEPA trigger at three (2%) mines; and NEPA analysis was triggered at two (1%) mines because they were located on Indian Lands. Twenty-three (19%) mines were located in states that have their own NEPA-equivalent statutes. In many cases, more than one federal agency may be involved in the NEPA process (e.g., Forest Service and BLM, based on location, or Forest Service and EPA, based on location and a NPDES discharge); in addition, state agencies may be responsible for carrying out their own NEPA-equivalent or alternative processes. When this occurs, a Memorandum of Understanding (MOU) is usually written among the various agencies describing their shared responsibilities in order to avoid duplication of efforts. When two or more federal and/or state agencies are involved, the agencies establish a formal agreement delineating which will act in the lead and cooperating roles. In some cases an EIS (or EA) may be developed that will satisfy both NEPA and a NEPA-equivalent state law.

The general makeup of the mines where NEPA is applicable is roughly similar to that of major mines. The NEPA-applicable mines are located in 11 states with all but one located in the western states. Nevada had the most NEPA-applicable major mines with 50% (69) of the total. Eighty-five percent (116) of the NEPA-applicable mines produced gold and/or silver, while 15% (21) produced copper. Seventy-six percent (104) of the NEPA-applicable major mines were open-pit, while 14% (19) were underground mines. Sixty-nine percent (95) used cyanide heap or vat leach, 20% (28) used flotation/gravity and 11% (15) used acid dump leach processing. Forty-seven percent (64) of the major mines subject to NEPA were still operating, 45% (61) have closed, one was in construction, six were in permitting, and five were withdrawn from consideration after undergoing the NEPA process.

EISs were performed at 82 (60%) of the 137 major mines subject to NEPA, either as part of new permitting actions or later expansions or other actions. EAs were performed at the remainder of the mines subject to NEPA. EISs and EAs were obtained by writing, e-mailing, and/or calling state and federal agencies, including the BLM, Forest Service, tribal agencies and by conducting library searches. The process of obtaining NEPA documents took approximately 16 months and involved numerous follow-up calls, and written and email contact. Of the 137 major mines subject to NEPA, 71 mines had documents that were obtained and reviewed. A total of 104 NEPA documents, either EISs or EAs, were reviewed for the 71 mines. The general characteristics of mines with reviewed EISs are similar to those of all major hard rock mines and all NEPA-eligible mines, as shown in Table ES-1.

EVALUATION OF WATER QUALITY PREDICTION INFORMATION IN NEPA DOCUMENTS

Information on the following elements related to water quantity and quality predictions was collected from the 104 NEPA documents: geology/mineralization; climate; hydrology; field and laboratory tests performed; constituents of concern identified; predictive models used; water quality impact potential; mitigation; potential water quality impacts; predicted water quality impacts; and discharge information. There are two types of water quality predictions made in EISs: "potential" water quality, which leans toward worst-case water quality that does not take mitigation into account; and "predicted" water quality, which does consider the beneficial effects of mitigation. Both types of water quality predictions were recorded and used for subsequent comparisons to actual water quality. For each type of information collected from the NEPA documents, a score was derived to characterize the element (e.g., geology/ mineralization used six scores, including one for no information provided). The scoring allowed numeric summaries (percentages) to be calculated based on the information collected from the NEPA documents. The results for the EIS information collected for each mine reviewed in detail (71 mines, 104 EISs) are contained in Section 5 of the report. Limited information on certain water quality elements is contained in Table ES-4.

A preliminary evaluation of the availability of operational water quality information was performed before selection of the case study mines. Operational and post-operational water quality information was available from EISs conducted after the new project EIS, especially for the states of Alaska, Montana and Idaho, where multiple EISs were often available. In other states, such as Arizona, California, Nevada and Wisconsin, technical reports and water quality data were available from state agencies that regulate mining activities.

SELECTION OF CASE STUDY MINES

The case study mines were selected based on:

- the ease of access to information on operational water quality
- the variability in general categories such as geographic location, commodity type, extraction and processing methods, and
- the variability in EIS elements related to water quality, such as climate, proximity to groundwater and surface water resources, acid drainage potential and contaminant leaching potential.

Case studies were developed for the twenty-five mines listed in Table ES-2.

Table ES-1. Comparison of General Categories for All Hard Rock Mines, NEPA-eligible Mines and Mines with Reviewed EISs (% of mines in sub-category)

Category	Sub-category	Major Mines (%)	NEPA-eligible Mines (%)	Mines with Reviewed EISs (%)
Location	Alaska	4.4%	5.1%	9.9%
	Arizona	10.9%	9.5%	11.3%
	California	8.2%	9.5%	11.3%
	Colorado	4.9%	0.0%	0.0%
	Idaho	7.7%	4.4%	8.5%
	Michigan	0.5%	0.0%	0.0%
	Montana	8.2%	10.9%	18.3%
	Nevada	40.4%	50.4%	32.4%
	New Mexico	3.8%	2.2%	2.8%
	South Carolina	1.6%	0.0%	0.0%
	South Dakota	2.7%	0.7%	1.4%
	Utah	3.8%	2.9%	1.4%
	Washington	2.2%	2.9%	0.0%
	Wisconsin	0.5%	0.7%	1.4%
Commodity	Primary Gold	12.6%	12.4%	19.7%
	Primary Silver	7.1%	6.6%	7.0%
	Gold and Silver	62.8%	65.7%	54.9%
	Copper	16.4%	15.3%	19.7%
	Copper and Molybdenum	4.4%	2.9%	1.4%
	Molybdenum	2.2%	0.7%	1.4%
	Lead and Zinc	3.8%	3.6%	5.6%
	Platinum Group	1.1%	1.5%	2.8%
Extraction Methods	Underground	14.8%	13.9%	18.3%
	Open Pit	72.1%	75.9%	71.8%
	Underground + Open Pit	12.0%	10.2%	9.9%
Processing Methods	Heap or Vat Leach	65.6%	69.3%	62.0%
	Flotation and Gravity	24.0%	20.4%	26.8%
	Dump Leach (SX/EW)	12.0%	10.9%	11.3%
	Heap Leach	39.3%	38.7%	25.4%
	Vat Leach	9.3%	10.2%	14.1%
	Heap Leach and Vat Leach	16.9%	20.4%	22.5%
	Smelter	3.3%	1.5%	1.4%
Operational Status	Operating	44.8%	46.7%	49.3%
	Closed	48.6%	44.5%	36.6%
	In Construction	0.5%	0.7%	1.4%
	Permitting	3.8%	4.4%	7.0%
	Withdrawn	2.2%	3.6%	5.6%
Total number of mines in category		183	137	71

Table ES-2. Case Study Mines

Mine	State	Mine	State
Greens Creek	AK	Golden Sunlight	MT
Bagdad	AZ	Mineral Hill	MT
Ray	AZ	Stillwater	MT
American Girl	CA	Zortman and Landusky	MT
Castle Mountain	CA	Florida Canyon	NV
Jamestown	CA	Jerritt Canyon	NV
McLaughlin	CA	Lone Tree	NV
Mesquite	CA	Rochester	NV
Royal Mountain King	CA	Round Mountain	NV
Grouse Creek	ID	Ruby Hill	NV
Thompson Creek	ID	Twin Creeks	NV
Beal Mountain	MT	Flambeau	WI
Black Pine	MT		

The major characteristics of the case study mines were similar to those of all mines with reviewed EISs, as shown in Table ES-3. The availability of information on operational water quality was also a major factor in the selection of case-study mines. The highest percentage of case study mines was from Nevada, and this state had the highest percentage of mines for all major mines, NEPA-eligible mines, and mines with reviewed EISs. Somewhat higher percentages of mines from California and Montana were selected for case studies because of the ease of obtaining operational water quality information from these states. Similar percentages of gold and/or silver mines were selected for the case studies as were present in all mines with reviewed EISs. However, a lower percentage of primary copper mines was selected for case study because of the difficulty in obtaining operational water quality information on these facilities. Case study mines had very similar percentages as all mines with reviewed EISs in terms of extraction and processing methods. In terms of operational status, no case study mines were in construction, in permitting, or withdrawn because operational water quality information would not be available for mines in these types of operational status.

Case study mines were also similar to all mines with reviewed EISs in terms of EIS elements related to water quality, as shown in Table ES-4. The elements listed in Table ES-4 are considered "inherent" factors that may affect water quality conditions. That is, these elements are related to conditions that either relate to climatic and hydrologic conditions at and near the mine site (in the case of climate, and proximity to water resources) or to qualities of the mined materials that may affect water quality (in the case of acid drainage and contaminant leaching potential). For a number of mines, little or no information on these elements was available in initial EISs, but subsequent NEPA documents either contained the first information or contained improved information after water quality conditions developed at the mine site during and after operation. Therefore, for acid drainage and contaminant leaching potential, the highest documented potential in any of the EISs was recorded.

Case study mines were similar to all mines with reviewed EISs in terms of climate and proximity to surface water resources. When compared to all mines with reviewed EISs, a higher percentage of case study mines had shallower depths to groundwater. However, six of the case study mines had groundwater depths greater than 50 feet below the ground surface. In terms of acid drainage potential, lower percentages of case study mines had low and high acid drainage potential, but higher percentages had moderate acid drainage potential. Therefore, the case study mines provide a somewhat more evenly distributed range of acid drainage potentials than all mines with reviewed EISs. Case study mines had nearly identical percentages of mines with low and high contaminant leaching potential, but more case study mines had moderate acid drainage potential, reflecting fewer mines in the "no information" category for case study mines.

Table ES-3. Comparison of General Categories for All Mines with Reviewed EISs and Case Study Mines (% of mines in subcategory)

Category	Subcategory	All Mines with Reviewed EISs	Case Study Mines
Location	Alaska	10%	4%
	Arizona	11%	8%
	California	11%	24%
	Colorado	0%	0%
	Idaho	9%	8%
	Michigan	0%	0%
	Montana	18%	24%
	Nevada	32%	28%
	New Mexico	3%	0%
	South Carolina	0%	0%
	South Dakota	1%	0%
	Utah	1%	0%
	Washington	0%	0%
	Wisconsin	1%	4%
Commodity	Primary Gold	20%	12%
	Primary Silver	7%	4%
	Gold and Silver	55%	64%
	Copper	20%	4%
	Copper and Molybdenum	1%	4%
	Molybdenum	1%	4%
	Lead and Zinc	6%	4%
	Platinum Group	3%	4%
Extraction Methods	Underground	18%	16%
	Open Pit	72%	76%
	Underground + Open Pit	10%	8%
Processing Methods	Heap and/or Vat Leach	62%	72%
	Flotation and Gravity	27%	28%
	Dump Leach (SX/EW)	11%	8%
	Heap Leach	25%	20%
	Vat Leach	14%	16%
	Heap Leach and Vat Leach	23%	32%
	Smelter	1%	0%
Operational Status	Operating	49%	52%
	Closed	37%	48%
	In Construction	1%	0%
	Permitting	7%	0%
	Withdrawn	6%	0%
Total number of mines		71	25

Table ES-4. Comparison of EIS Elements for All Mines with Reviewed EISs and Case Study Mines (% of mines with sub-element)

Element	Sub-element	All Mines with Reviewed EISs	Case Study Mines
Climate	Dry/Arid	20%	20%
	Dry/Semi-Arid	35%	28%
	Humid Subtropical	4%	12%
	Marine West Coast	4%	4%
	Boreal Forest	28%	32%
	Continental	3%	4%
	Sub-Arctic	4%	0%
Surface Water Proximity	No information	7%	4%
	Perennial Streams >1 mile	26%	24%
	Perennial streams <1 mile	25%	28%
	Perennial streams on site	44%	44%
Groundwater Proximity	No information	12%	4%
	Groundwater >200 ft deep	16%	8%
	Groundwater 50-200 ft deep	13%	16%
	Groundwater 0-50 ft deep/springs on site	59%	72%
Acid Drainage Potential (highest)	No information	9%	8%
	Low	58%	48%
	Moderate	6%	32%
	High	27%	12%
Contaminant Leaching Potential (highest)	No information	22%	12%
	Low	32%	32%
	Moderate	30%	40%
	High	17%	16%
Total number of mines		71	25

Overall, the case study mines display a variability in geographic location, commodity type, extraction and processing methods and in EIS elements related to water quality. Considering the additional limitation of having readily accessible operational water quality information, the case study mines reflect well the distribution of general categories and water quality-related elements that are present in the larger subsets of hard rock mines in the United States.

Case studies for each mine contain information collected from EISs and other documents, information on actual water quality, a comparison of predicted and actual water quality, and an analysis of the causes of water quality impacts and prediction errors.

COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Operational and post-operational water quality information was collected from EISs conducted after the new project EIS for mines in Alaska, Montana and Idaho. Interviews of state agency personnel were conducted in California, Montana, Nevada and Wisconsin. Technical reports and water quality data from state agencies that regulate mining were collected for mines in Arizona, California, Nevada and Wisconsin. In some cases, the water quality data showed pre-mining and operational water quality, but baseline data were generally difficult to obtain. The information collected on actual water quality conditions was held in databases or in electronic and paper files for comparison to predicted water quality.

For this evaluation, a water quality impact is defined as increases in water quality parameters as a result of mining operations, whether or not an exceedence of water quality standards or permit levels has occurred. Information on whether groundwater, seep, or surface water concentrations exceeded standards as a result of mining activity is also included. Nearly all the EISs reviewed reported that they expected acceptable water quality (concentrations lower than relevant standards) after mitigation were taken into account. Indeed, if this prediction was not made in the EIS, the regulatory agency would not be able to approve the mine (with certain exceptions, such as pit water quality, in states where pit water is not considered a water of the state).

A comparison between potential (pre-mitigation), predicted, and actual surface water quality for the case study mines is presented in Table ES-5. Sixty percent of the case study mines (15/25) had mining-related exceedences in surface water. Of the mines with surface water quality exceedences, four (17%) noted a low potential, seven (47%) a moderate potential, two a high potential, and three had no information in their EISs for surface water quality impacts in the absence of mitigation measures. For the mines with surface water quality exceedences, only one mine, the McLaughlin Mine in California, was correct in predicting a moderate potential for surface water quality impacts with mitigation in place. However, this mine predicted low acid drainage potential, yet acid drainage has developed on site. Of the mines without surface water quality exceedences (7 or 28%), all were correct thus far in predicting no impacts to surface water with mitigation in place. Three of the seven are desert mines in California, one (Stillwater in Montana) has had increases in contaminant concentrations but no exceedences, and the other three have had no exceedences or increases in mining-related contaminant concentrations in surface water to date. Therefore, most case study mines predicted no impacts to surface water quality after mitigation are in place, but at the majority of these mines, impacts have already occurred.

A comparison between potential (pre-mitigation), predicted, and actual groundwater quality for the case study mines is presented in Table ES-6. The majority (64% or 16/25) of the case study mines had exceedences of drinking water standards in groundwater. However, exceedences at three of the mines, all in Nevada, may be related to baseline conditions; therefore, 52% of the case study mines clearly had mining-related exceedences of standards in surface water. Of the 13 mines with mining-related exceedences in groundwater, only two noted a low potential for groundwater quality impacts in the original EIS. The majority (9 or 69%) stated that there would be a moderate potential, and two stated there was a high potential for groundwater impacts in the absence of mitigation. In terms of predicted (post-mitigation) groundwater quality impacts, 77% (10/13) of the mines with exceedences predicted low groundwater quality impacts in their EISs, including mines predicting low impacts in the original EIS.

Of the mines with mining-related groundwater quality exceedences (13), only one mine – the same mine that correctly predicted that there would be surface water exceedences (McLaughlin, CA), was correct in predicting a high potential for groundwater quality impacts with mitigation in place; the others predicted a low potential (not exceeding standards) in at least one EIS. Of the mines without groundwater quality exceedences (5 or 25%), all were correct in predicting no impacts to surface water with mitigation in place. Again, three of the five are desert mines in California, one (Stillwater, MT) has had increases in contaminant concentrations but no exceedences, and the other (Greens Creek, AK) has had mining-related exceedences in seeps. Therefore, most mines predict no impacts to groundwater quality after mitigation were in place, but in the majority of case study mines, impacts have occurred.

Therefore, as with surface water, the predictions made about groundwater quality impacts without considering the effects of mitigation were somewhat more accurate than those made taking the effects of mitigation into account. Again, the ameliorating effect of mitigation on groundwater quality was overestimated in the majority of the case study mines.

A comparison between acid drainage and development for the case study mines is presented in Table ES-7a. Of the 25 case study mines, nine (36%) have developed acid drainage on site to date. Nearly all the mines (8/9) that developed acid drainage either underestimated or ignored the potential for acid drainage in their EISs.

Table ES-5. Summary of Predicted and Actual Impacts to Surface Water Resources at Case Study Mines

Element	Number/Total	Percentage
Mines with mining-related surface water exceedences	15/25	60%
Mines with surface water exceedences that predicted low impacts without mitigation	4/15	27%
Mines with surface water exceedences that predicted low impacts with mitigation	11/15	73%

Table ES-6. Summary of Predicted and Actual Impacts to Groundwater Resources at Case Study Mines

Element	Number/Total	Percentage
Mines with mining-related groundwater exceedences	13/25	52%
Mines with groundwater exceedences predicting low impacts without mitigation	2/13	15%
Mines with groundwater exceedences predicting low impacts with mitigation	10/13	77%

Table ES-7a. Summary of Acid Drainage Potential Predictions and Results for Case Study Mines

Element	Number/Total	Percentage
Mines predicting low acid drainage potential	18/25	72%
Mines that have developed acid drainage	9/25	36%
Mines with acid drainage that predicted low acid drainage potential	8/9	89%

The majority of the case study mines (18/25 or 72%) predicted low potential for acid drainage in one or more EISs. Of the 25 case study mines, 36% have developed acid drainage on site to date. Of these 9 mines, 8 (89%) predicted low acid drainage potential initially or had no information on acid drainage potential. The Greens Creek Mine in Alaska initially predicted moderate acid drainage potential but later predicted low potential for acid drainage for an additional waste rock disposal facility. Therefore, nearly all the mines that developed acid drainage either underestimated or ignored the potential for acid drainage in their EISs.

Of the 25 case study mines, 19 (76%) had mining-related exceedences in surface water or groundwater. However, nearly half of the mines with exceedences (8/19 or 42%) predicted low contaminant leaching potential in their EISs. The constituents that most often exceeded standards or that had increasing concentrations in groundwater or surface water included toxic heavy metals such as copper, cadmium, lead, mercury, nickel, or zinc (12/19 or 63% of mines), arsenic and sulfate (11/19 or 58% of mines for each) and cyanide (10/19 or 53% of mines).

Eight case study mines predicted low contaminant leaching potential (Table ES-7b). Of these eight mines, five (63%) had exceedences of standards in either surface water or groundwater or both after mining began. The three mines that predicted low contaminant leaching potential and had no exceedences of water quality standards were the three California desert mines: American Girl, Castle Mountain, and Mesquite.

Table ES-7b. Summary of Contaminant Leaching Potential Predictions and Results for Case Study Mines (percentages)

Element	Number/Total	Percentage
Mines predicting low contaminant leaching potential	8/25	32%
Mines with mining-related exceedences in surface water or groundwater	19/25	76%
Mines with exceedences that predicted low contaminant leaching potential	8/19	42%
Mines with exceedences that predicted moderate contaminant leaching potential	8/19	42%
Mines with exceedences that predicted high contaminant leaching potential	3/19	16%

Stated another way, 21 of the 25 case study mines (84%) had exceedences of water quality standards in either surface water or groundwater or both. The exceedences at two of these mines may be related to baseline conditions. Therefore, 76% of the case study mines had mining related exceedences in surface water or groundwater (Table ES-7b). Of the remaining 19 mines, 42% (eight) predicted low contaminant leaching potential (or had no information), 42% (eight) predicted moderate contaminant leaching potential, and only three (16%) predicted high contaminant leaching potential. Therefore, nearly half of the mines that had exceedences of water quality standards underestimated or ignored the potential for contaminant leaching potential in EISs. The constituents that most often exceeded standards or that had increasing concentrations in groundwater or surface water included toxic heavy metals such as copper, cadmium, lead, mercury, nickel, or zinc (12/19 or 63% of mines), arsenic and sulfate (11/19 or 58% of mines for each), and cyanide (10/19 or 53% of mines).

CAUSES OF WATER QUALITY IMPACTS AND PREDICTION ERRORS

Inherent Factors Affecting Water Quality at Mine Sites

This study attempts to determine if there are certain factors that make a mine more or less likely to cause water quality problems and more or less likely to accurately predict future water quality. Such factors could include inherent characteristics of the mined materials and the mine, management approaches to handling mined materials and water, and the type and number of geochemical tests that are performed on mined materials. The inherent factors evaluated include: geology and mineralization; proximity to water resources and climatic conditions; and geochemical characteristics of mined materials, such as acid drainage and contaminant leaching potential.

The relationship between inherent hydrologic and geochemical characteristics and water quality impacts shows that mines with close proximity to surface water or groundwater resources and with a moderate to high acid drainage or contaminant leaching potential have an increased risk of impacting water quality.

Surface water impacts for the mines with close proximity to surface water and high acid drainage or contaminant leaching potential are compared to surface water impacts for all the case study mines in Table ES-8. Overall, for the 13 mines with close proximity to surface water and high acid drainage or contaminant leaching potential, 12 (92%) have had some impact to surface water as a result of mining activity. For all case study mines, only 64% had some surface water quality impact. Eleven of the 13 (85%) have had exceedences of standards or permit limits in surface water as a result of mining activity.

Table ES-8. Surface Water Quality Impacts for Mines with Close Proximity to Surface Water and Elevated Acid Drainage Potential Compared to Surface Water Impacts for All Case Study Mines

	# Mines	Percent (%) with Impact to Surface Water	Percent (%) with Exceedences of Standards in Surface Water	Percent (%) with Exceedences that Predicted No Exceedences
Mines with close proximity to surface water and elevated acid drainage and contaminant leaching potential	13	92 (12/13)	85 (11/13)	91 10/11)
All case study mines	25	64 (16/25)	60 (15/25)	73 (11/15)

Of the 11 mines with surface water exceedences, ten (91%) predicted that surface water standards would not be exceeded. Considering the two mines that accurately predicted no surface water exceedences (Stillwater and Flambeau) and the one that accurately predicted exceedences (McLaughlin), 77% of mines with close proximity to surface water or direct discharges to surface water and moderate to high acid drainage or contaminant leaching potential underestimated actual impacts to surface water. For all case study mines, 73% of the mines with surface water quality exceedences predicted that there would be no exceedences. Compared to all case study mines, higher percentages of mines with close proximity to surface water and elevated acid drainage or contaminant leaching potential had surface water quality impacts and exceedences. EIS water quality predictions made before the ameliorating effects of mitigation were considered ("potential" water quality impacts) were more accurate at predicting operational water quality than predictions based on assumed improvements from mitigation.

Groundwater impacts for the mines with close proximity to groundwater and high acid drainage or contaminant leaching potential are compared to groundwater impacts for all the case study mines in Table ES-9. Of the 15 mines with close proximity to groundwater and high acid drainage or contaminant leaching potential, all but one (93%) have had mining-related impacts to groundwater, seeps, springs or admit water. For all case study mines, only 56% had mining-related impacts to groundwater. For the 15 mines with close proximity to groundwater and elevated acid drainage or contaminant leaching potential, 13 or 87% had mining-related exceedences in groundwater. For all case study mines, only 52% had exceedences in groundwater.

Table ES-9. Groundwater Quality Impacts for Mines with Close Proximity to Groundwater and Elevated Acid Drainage Potential Compared to Groundwater Impacts for All Case Study Mines

	# Mines	Percent (%) with Impact to Groundwater or Seeps	Percent (%) with Exceedences of Standards in Groundwater or Seeps	Percent (%) with Exceedences that Predicted No Exceedences
Mines with close proximity to groundwater and elevated acid drainage and contaminant leaching potential	15	93 (14/15)	93 (14/15)	86 (12/14)
All case study mines	25	68 (17/25)	68 (17/25)	52 (13/25)

These results, although not comprehensive, suggest that the combination of proximity to water resources (including discharges) and moderate to high acid drainage or contaminant leaching potential does increase the risk of water quality impacts and is a good indicator of future adverse water quality impacts. Although this finding makes intuitive sense from a risk perspective, a comprehensive study of cause and effect has never been conducted. Mines with these inherent factors are the most likely to require perpetual treatment to reduce or eliminate the long-term adverse impacts to surface water resources. Although all mines must rely on well executed mitigation measures to ensure the integrity of water resources during and after mining, mines with the inherent factors identified in this study must have mitigation measures that are even more carefully designed to avoid water quality impacts.

FAILURE MODES AND ROOT CAUSES OF WATER QUALITY IMPACTS

This section identifies the underlying causes of water quality impacts at the case study mines. It uses information gathered from the case studies and conducts a “failure modes” and “root cause" analysis. A failure is an outcome that is different than intended or predicted. A failure mode is the general type of failure that occurred or is predicted to occur (e.g., prediction failure, mitigation failure), while a root cause is the underlying, more specific, reason for the failure. The objective of the analysis presented in this section is to identify the most common types and causes of failures in protecting water quality at existing mines so that the failures can be prevented in the future. Results from this analysis can be used to make recommendations for improving both the policy and the scientific and engineering underpinnings of EISs.

Methodology and Approach

The approach uses existing (“historical”) information from the 25 case study mines with EISs to identify the causes of water quality impacts that occurred during mining operations. In contrast, most similar risk analyses are conducted before operations begin and focus on generating predictions from engineering design information (e.g., likelihood of failure based on factor of safety calculations). Because our approach is retrospective rather than prospective, we know unequivocally whether a prediction has failed or a water quality failure has occurred. Therefore, the focus of this analysis is to determine what caused the failure to occur. The information used to determine how failure occurred is contained in the case studies, which summarize and compare water quality predictions in EISs with actual water quality conditions during mining operations.

Types of Characterization Failures

There are two types of characterization failures identified in the case studies: hydrologic and geochemical. Inaccuracies in hydrologic and geochemical characterization can lead to a failure to recognize or predict water quality impacts. The primary root causes of hydrologic characterization failures identified in this study are:

- dilution overestimated
- lack of hydrological characterization
- amount of discharge overestimated
- size of storms underestimated.

The primary root causes of geochemical characterization failures identified are:

- lack of adequate geochemical characterization
- sample size and/or representativeness.

The other failure mode identified in the case studies is mitigation failure in which the primary root causes are:

- mitigation not identified, inadequate or not installed
- waste rock mixing and segregation not effective
- liner leak, embankment failure or tailings spill
- land application discharge not effective.

Table ES-10 shows the various failures modes, root causes and identifies various mines that serve as examples of the failure modes. The results are summarized in Table ES-11 and are as described below.

Six of 25 mines exhibited inadequacies in hydrologic characterization.

- At two of the mines, dilution was overestimated.
- At two of the mines, a lack of hydrologic characterization was noted.
- At one of the mines, the amount of discharge generated was underestimated.
- At one of the mines, the size of storms was underestimated.

Eleven of 25 mines exhibited inadequacies in geochemical characterization. Geochemical failures resulted from:

- assumptions made about the geochemical nature of ore deposits and surrounding areas (e.g., mining will only be done in oxidized area)
- site analogs inappropriately applied to a new proposal (e.g., historic underground mine workings do not produce water or did not indicate acid generation)
- inadequate sampling (e.g., geochemical characterization did not indicate potential due to composite samples or samples not being representative of actual mining)
- failure to conduct and have results for long-term contaminant leaching and acid drainage testing procedures before mining begins
- failure to conduct the proper tests, or to improperly interpret test results, or to apply the proper models.

Sixteen of 25 mines exhibited failures in mitigation measures.

- At three of the mines mitigation was not identified, inadequate, or not installed.
- At four of the mines waste rock mixing and segregation was not effective.
- At nine of the mines liner leaks, embankment failures or tailings spills caused impacts to water resources.
- At one mine, land application disposal resulted in impacts to water resources.

Table ES-10. Water Quality Predictions Failure Modes, Root Causes and Examples from Case Study Mines

Failure Mode	Root Cause	Examples
Hydrologic Characterization	Lack of hydrologic characterization	Royal Mountain King, CA; Black Pine, MT
	Dilution overestimated	Greens Creek, AK; Jerritt Canyon, NV
	Amount of discharge underestimated	Mineral Hill, MT
	Size of storms underestimated	Zortman and Landusky, MT
Geochemical Characterization	Lack of adequate geochemical characterization	Jamestown, CA; Royal Mountain King, CA; Grouse Creek, ID; Black Pine, MT
	Sample size and/or representation	Greens Creek, AK; McLaughlin, CA; Thompson Creek, ID; Golden Sunlight, MT; Mineral Hill, MT; Zortman and Landusky, MT; Jerritt Canyon, NV
Mitigation	Mitigation not identified, inadequate, or not installed	Bagdad, AZ; Royal Mountain King, CA; Grouse Creek, ID
	Waste rock mixing and segregation not effective	Greens Creek, AK; McLaughlin, CA; Thompson Creek, ID; Jerritt Canyon, NV
	Liner leak, embankment failure or tailings spill	Jamestown, CA; Golden Sunlight, MT; Mineral Hill, MT; Stillwater, MT; Florida Canyon, NV; Jerritt Canyon, NV; Lone Tree, NV; Rochester, NV; Twin Creeks, NV
	Land application discharge not effective	Beal Mountain, MT

Table ES-11. Summary of Failure Modes for Case Study Mines

Failure Mode	Number of Case Study Mines Showing Failure Mode	Percent of Case Study Mines Showing Failure Mode
Hydrologic Characterization	6	24%
Geochemical Characterization	11	44%
Mitigation	16	64%

CONCLUSIONS AND RECOMMENDATIONS

Identification of Risk and Prevention of Impacts

- Actual water quality impacts are closer to potential (pre-mitigation) rather than predicted (post-mitigation) impacts in EISs; therefore, the threshold for significance determinations, and thus EIS (rather than EA) analysis, should be potential rather than predicted impacts.

- Cyanide is not specifically identified as a contaminant of concern often enough; whenever cyanide is being used in heap or vat leaching or flotation, it should be listed as a potential contaminant of concern.

- A minimum and relatively consistent set of geochemical tests should be required by federal and state mining agencies. See the companion report (*Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State- of-the-Art*) for recommendations for minimum required geochemical testing.

- Mines with close proximity or discharges to water resources, moderate to high acid drainage and/or contaminant leaching potential should undergo more scrutiny by agencies in the permitting process than mines with low inherent water quality impact factors.

- Hydrologic characterization failures are most often caused by over-estimation of dilution, failure to recognize hydrologic features and underestimation of water production quantities. They can be addressed by requiring adequate hydrologic characterizations and making environmentally conservative assumptions about water quality and quantity.

- Lack of adequate geochemical characterization is the single-most identifiable root cause of water quality prediction failures. Improvements in geochemical characterization can provide the greatest contribution to ensuring accurate water quality predictions at hardrock mine sites. As noted in the companion report, the same geochemical test units should be used for testing of all sources and parameters used to predict water quality impacts. In addition, more extensive information on mineralogy and mineralization should be included in EISs, and more attention should be paid to uncertainties in geochemical and hydrologic characterization.

- Mixing and segregation mitigation failures occur at a moderate frequency and are typically caused by using too little neutralizing material and not effectively isolating acid generating material from nearby water resources. This can be addressed by requiring adequate geochemical and hydrologic characterization and minimizing transport along hydrologic pathways.

- Mitigation frequently fails to perform according to plan. It is important to consider the likelihood and consequences of mitigation failure in EISs and identify additional mitigation measures that can be installed if failure occurs. Multiple mitigation measures (e.g., installation of liner and leachate collection system or pump-back system) should be required in most cases and planned for in the design phase.

- Improvements are needed in the prediction of appropriate mitigation measures. Preventive mitigation measures are more cost effective and environmentally protective than remediation after impacts have occurred.

- EISs for new mines should include comprehensive baseline water quality, hydrologic, and geochemical evaluations and careful and supportable identification of mitigation measures, including an evaluation of potential mitigation failures.

Data and Data Quality Issues

- Operational and post-operational water quality information for hard rock mine sites should be readily accessible to the public in a user-friendly web-based format.

- Information provided to the public should include: maps clearly showing the location of mine units, streams, and surface water and groundwater sampling locations; identification of facilities/source areas associated (upgradient) with wells and other sampling points; pre-mining and baseline/background water quality and quantity information; well depths; groundwater elevations in monitoring wells; and water quality data for all monitoring locations.

- In many cases existing conditions were explained by baseline water quality conditions with limited baseline water quality information. An independent review of baseline water quality data for hard rock mines should be conducted to verify those claims.

- With the cooperation of industry and regulators, a more systematic and complete effort should be undertaken to compare water quality predictions against actual water quality impacts as a follow-up to this study.

1. INTRODUCTION

When a mine is permitted in the United States, the project proponent (i.e., mining company) must ensure the regulatory agency or agencies that groundwater and surface water quality will not be adversely affected by the proposed mining operations. Based on laboratory and field characterization tests, and in some cases water quality modeling, qualitative or quantitative predictions of operational and post-closure water quality are presented. However, the validity of these predictions is rarely checked after mining begins. During the course of this investigation no single document was discovered comparing National Environmental Policy Act (NEPA) document predictions to actual water quality. This study is the first such effort to evaluate the reliability of water quality predictions for large hardrock mines.

This study is the second in a two-part series on prediction of water quality at hardrock mines. The first report, titled *Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art* (Maest et al., 2005) provides an overview and critique of the mine characterization and modeling techniques that are being used for prediction of water quality at mines in the U.S. and internationally. The objective of the second study, reported in this document, is to review the history and reliability of water quality predictions for major hardrock mines in the United States. In addition, factors contributing to the reliability of the water quality forecasts are identified, and recommendations are presented for improving water-quality predictions.

1.1. METHODOLOGY AND APPROACH

This project utilized water quality predictions made in Environmental Impact Statements (EISs) because EISs require water quality predictions to be made as part of the regulatory review process in NEPA. This report is not intended to address the regulatory process itself but rather the underlying scientific and technical processes, which are employed in EISs to predict water quality impacts.

The overall project methodology/approach consisted of the following phases:

- define and identify all major hardrock mines in the U.S
- identify NEPA/EIS eligibility of major hardrock mines
- identify and gather EISs and related documentation for major mines
- review, compile and analyze relevant EIS documents and related information on water quality predictions
- gather, review and document in case study format EISs and water quality history information for selected mine sites
- compare EIS predictions with actual water quality information for the selected mines
- identify failure modes and root causes of failures to predict water quality impacts
- develop conclusions and recommendations about the effectiveness and regulatory application of the science underlying water quality predictions at hardrock mines

A database (Excel spreadsheet) was created to catalogue general operational and environmental information from NEPA documents and other sources as well as information on discharges to groundwater and surface water for major and mines subject to NEPA. The data collected include the following:

- location (state and county if available)
- ownership
- commodity (gold, silver, copper, molybdenum, lead, zinc, platinum group metals)
- mining (underground, open pit) and processing methods (heap leach, vat leach, flotation, gravity, dump leach (sx/ew), smelter)
- operational status (year production initiated, present status, year closed, projected year closed)
- disturbance and financial assurance (permitted and/or actual disturbance on BLM, Forest Service, private, state, and Native American Indian Lands; current financial assurance amount, bankruptcy status)
- NEPA applicability by BLM, Forest Service, Corps of Engineers, EPA, Indian Lands, state required
- NEPA documentation including year of document, proposed action, document type (EA, EIS, SEIS)

- record of NEPA document requests and retention
- EIS information (summary of information on geology/mineralization; climate; hydrology; field and lab tests performed; constituents of concern identified; predictive models used; water quality impact potential; mitigation; predicted water quality impacts; discharge information)
- National Pollutant Discharge Elimination System (NPDES) permit information (permit number, major or minor permit, whether reported on EPA ECHO database)

The major challenge for this study was obtaining reliable operational water quality data against which predictions can be measured or evaluated. The ease of obtaining such information varies dramatically from state to state. In some states, NEPA or its equivalent that requires water quality predictions, is applied to all mines in the state, while in other states, NEPA derived water quality predictions are applicable only to mines on public lands. In some states, water quality data are available in electronic forms while in others, only paper copies of water quality data are available. In this study we limit our in-depth case study analysis to mines subject to the NEPA process requiring water quality predictions. Therefore, the focus is predominantly on mines on public lands. The mines selected for case study reflect the general population of large hardrock mines in terms of their geographic distribution, commodity types, and other factors. Generally, mines that have exhibited water quality impacts have more water quality data and analysis than mines without notable environmental impacts. In order to balance the analysis, an effort was made to include not only mines with notable impacts in the case studies, but also mines without notable impacts.

For the case study mines, water quality conditions after mining began are compared to water quality predictions and baseline water quality data. If water quality impacts did occur but were not predicted, the causes of the impacts are provided to the extent practicable. Based on this analysis, recommendations for improvements in the scientific underpinnings of the predictions used in the regulatory process are made.

The study is broken into the following sections after the introduction:

- Section 2 provides background information in NEPA and EISs related to water quality predictions at mine sites.
- Section 3 provides a primer on water quality prediction methods and models that have historically been and are presently in use.
- Section 4 provides the basis for defining major and hardrock mines subject of NEPA and summarizes the information describing the major and NEPA applicable mines on state and federal agency basis.
- Section 5 contains information on water quality predictions for each of the 71 major mines where complete information was available. The information collected includes geology and mineralization, climate hydrology, field and lab tests performed, constituents of concern identified, predictive models used, water quality impact potential, mitigation, predicted water quality impacts and discharge information.
- Section 6 consists of case study summaries for selected mines, focusing on predicted and actual water quality impacts.
- Section 7 contains the general results of the study, including a discussion of inherent factors that may predispose a mine to water quality impacts.
- Section 8 identifies the causes for failed predictions and contains recommendations for improving predictions and the regulatory process related to predictions.
- Appendix A provides major mine statistical information by state and federal agency including location (state and where available, county information), commodity produced, extraction and processing methods, and operational status.
- Appendix B provides more complete information on NEPA documents and water quality data.

2. NEPA AND WATER QUALITY PREDICTIONS

The following sections contain a general description of the National Environmental Policy Act (NEPA) and information in the Act related to scientific analysis and water quality predictions.

2.1. NATIONAL ENVIRONMENTAL PROTECTION ACT

When Congress passed the National Environmental Policy Act (NEPA) in 1969 it was heralded as the foundation of modern American environmental protection by providing a comprehensive national policy for focusing on environmental concerns (CEQ 1997). NEPA does not work by mandating that federal agencies achieve particular substantive environmental results. Rather, NEPA requires federal agencies to take a "hard look" at the environmental impacts of certain proposed projects to ensure the necessary mitigation or other measures are employed to meet federal regulations and other applicable (such as state) requirements.

NEPA requires the consideration of the important potential environmental impacts of a proposed action through express statutory mandates, Council on Environmental Quality (CEQ) regulations, and individual federal agency-specific regulations. Further, the broad dissemination of information mandated by NEPA allows the public and other government agencies to participate in the environmental review process and to react to the effects of a proposed action as part of the permitting process.

To those ends, NEPA requires federal agencies proposing major actions that may substantially affect the quality of the human environment to prepare a detailed Environmental Impact Statement (EIS). A "major action" includes actions approved by permit or other regulatory action. EISs are required to describe different alternatives to the proposed action, including the "no action" alternative, in which the proposed action would not be implemented.

In order to determine whether or not a project will have a significant impact on the environment, the federal agency may prepare an Environmental Assessment (EA). If the agency determines, after preparation of the EA, that the project will not significantly impact the environment, then it may issue a Finding of No Significant Impact (FONSI). Otherwise, if the agency finds that the project *may* have a significant impact on the environment, then it must prepare an EIS. In many cases the agency will prepare an EIS from the outset, particularly where the project is likely to be more controversial. EISs are required to describe different alternatives to the proposed action, including the "no action" alternative, in which the proposed action would not be implemented.

The federal agency must consider three types of impacts – direct, indirect, and cumulative. Direct effects are those that are caused by the action and occur at the same time and place. Indirect effects are those that are caused by the action and occur later in time or farther removed in distance but are still reasonably foreseeable. Indirect effects may include effects on air and water and other natural systems, including ecosystems. A project's "cumulative impact" is the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

2.2. SCIENTIFIC ANALYSIS IN THE NEPA PROCESS

The federal agencies are required to describe the environment of the areas to be affected or created by the alternatives under consideration. In order to do so, a baseline against which to compare predictions of the effects of the proposed action is considered to be critical to the NEPA EIS process.

NEPA and its implementing regulations require all federal agencies to:

> [I]nsure the professional integrity, including scientific integrity of the discussions and analysis in environmental impact statements. [Agencies] shall identify any methodologies used and shall make explicit reference by footnote to the scientific and other sources relied upon for conclusions in the statement (40 CFR 1502.24).

Further, the regulations mandate that all NEPA documents be “supported by evidence that the agency has made the necessary environmental analysis” (40 CFR § 1502.1). Consequently, federal agencies have a duty to disclose the underlying scientific data and rationale supporting the conclusions and assumptions in an EIS. Unsupported conclusions and assumptions violate NEPA. The federal courts pay particular attention to this requirement and have found that federal agencies are required to provide the underlying environmental data that are relied upon in the NEPA process. The scientific data and rationale are typically contained in appendices to an EIS.

The importance of scientific integrity and use of high-quality data in the NEPA analysis process cannot be overstated. To satisfy NEPA, the federal agencies “must explicate fully its course of inquiry, its analysis, and its reasoning.” (Dubois V. U.S. Department of Agriculture, 102 F.3d 1273, 1287 (1st Cir. 1996)). NEPA provides specific requirements in the case where data or scientific analyses are unavailable to the federal agency. The existence of incomplete or unavailable scientific information concerning significant adverse environmental impacts essential to a reasoned choice among alternatives triggers the requirements of 40 CFR § 1502.22. This provision requires the disclosure and analysis of the costs of uncertainty and the costs of proceeding without more and better information.

40 CFR § 1502.22 imposes three mandatory obligations in the face of scientific uncertainty: (1) a duty to disclose the scientific uncertainty; (2) a duty to complete independent research and gather information if no adequate information exists (unless the costs are exorbitant or the means of obtaining the information are not known); and (3) a duty to evaluate the potential, reasonably foreseeable impacts in the absence of relevant information, using a four-step process. The four step process involves:

1. a statement that such information is incomplete or unavailable;
2. a statement of the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts on the human environment;
3. a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment, and;
4. the agency's evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community. For the purposes of this section, "reasonably foreseeable" includes impacts which have catastrophic consequences, even if their probability of occurrence is low, provided that the analysis of the impacts is supported by credible scientific evidence, is not based on pure conjecture, and is within the rule of reason.

The requirement to conduct independent research when faced with incomplete or unavailable information insures agencies comply with NEPA’s central purpose “to obviate the need for speculation by insuring that available data is gathered and analyzed prior to the implementation of the proposed action.” “The federal courts have held that original research should be performed if necessary together with reasonable scientific supported forecasting and speculation.” (Save our Ecosystems at 1248-49 and at 1246 note 9)

3. THE SCIENCE OF WATER QUALITY PREDICTION AND MITIGATION

The science of predicting water quality at hardrock mine sites has been practiced for at least the past 30 years as part of the regulatory review process. Under NEPA, hardrock mines in the United States on federal land are required to estimate impacts to the environment, including direct impacts to water quality and indirect impacts that are later in time but still reasonably foreseeable (Kempton and Atkins, 2000; Bolen, 2002). Mines on private land in the United States may also be subject to state or federal processes that may or may not require prediction of potential impacts to water resources. A wide array of scientific approaches ha been used to predict water quality that could result from proposed construction, expansion, or other actions as described in the following sections.

3.1. SITE CONCEPTUAL MODEL

An accurate conceptual model is a necessary first step in successfully predicting water quality at a mine site (Mayer et al., 2002). A conceptual model is a qualitative description of the hydrology and chemistry of the site and their known and potential effect on mined and natural materials. It includes baseline conditions, sources (mining-related and natural), pathways, biophysicochemical processes, mitigation measures, and receptors. Information about sources and mitigation measures will generally come from the mine plan. Site conceptual models should include mitigation measures, and the effectiveness of mitigation measures on water quality should be evaluated.

A mine is an ever-evolving entity, and the site conceptual model must change as the mine evolves. Changes in the mine plan can appreciably affect future water quality. Short of a significant change, however, the accumulation of many small changes in the mine plan can make it difficult to accurately predict water quality. Therefore, predictions themselves must be continually updated as new environmental information from the mine site becomes available.

3.2. GEOCHEMICAL CHARACTERIZATION

The next step in predicting water quality at mines is the characterization of mined materials and the environment. For the purposes of this study, which focuses on water quality at hardrock mine sites, characterization is defined as field and/or laboratory tests or measurements that help define the physicochemical and biological environment that will be or has been mined and the potential for water quality impacts.

Different phases of mining present different opportunities for characterization. During the exploration phase, whole rock analysis, mineralogy, and acid-base accounting should be conducted as part of the delineation of the ore body, and long-term kinetic testing should be initiated. Information on baseline water quality and quantity (including information on similar areas that have already been mined, if relevant) and hydraulic properties should be gathered, and hydrogeochemical modeling for water quality prediction should be initiated.

During the development phase, information on geology, mineralogy, acid-base accounting, kinetic testing, and hydraulic properties should be continued, and more detailed hydrogeochemical modeling should be conducted. During this phase, bench and field scale testing should be conducted, and the effects of mining (e.g., dewatering) on groundwater potentiometric surfaces should be evaluated.

When active mining is underway, geochemical and hydrologic characterization of mined materials should be conducted (including sampling of leachate and testing of hydraulic properties of mined materials and changes in groundwater elevations in response to mining). Up gradient and downgradient water quality in receptors should be sampled, and the first comparisons of predicted and actual water quality can be conducted.

During the closure, reclamation, and post-closure phases of mining, receptor sampling and measurement of changes in groundwater levels should be continued, and improved comparisons of predicted and actual water quality will be possible. During any phase of mining, the extent of a geochemical characterization program should be dictated by site conditions and the nature of the deposit, with complex geology, hydrology, and mineralogy requiring a greater effort.

3.3. WATER QUALITY MODELING

The stages in developing a predictive hydrogeochemical model of water quality for a mine site include:
- developing a site-wide conceptual model
- selecting an appropriate computational code
- gathering site-specific geologic, geochemical, and hydrologic data and fundamental (e.g., thermodynamic) information as inputs for the model
- calibration of the model (for hydrologic models)
- predictive modeling using the model.

Information needed for a site-wide conceptual model includes:
- baseline conditions (hydrogeologic units, existing waste, water quantity/quality, climate)
- sources (location, volume, chemistry)
- pathways (location, connectivity)
- processes (hydrologic, air flow, geochemical, biological)
- receptors (location, water quality/quantity)
- mitigation measures (type, purpose, natural mitigation, effectiveness).

Selection of a computer code to develop a prediction of water quality should be based on factors such as: 1) modeling objectives; 2) capability of the code to simulate important processes affecting water quality at the mine site, as described by the site conceptual model(s); 3) ability of the code to simulate spatial and temporal distribution of key input parameters and boundary conditions; 4) availability of the code and its documentation to the public; and 5) ease of use of the code, including availability of pre- or post-processors and graphical interfaces.

Site-specific inputs to computer codes are needed to make a model that will have relevance to a given mine site. The quality and representativeness of input data will affect the results of the models. Site-specific inputs to hydrogeochemical codes used to predict water quality are similar to certain information needed for conceptual models and can include geologic, hydraulic/hydrologic, chemical, mineralogic, and climatic data.

Model calibration is the process of comparing site-specific observations (e.g., stream flows, groundwater elevations, or pit lake concentrations) with model simulations. Calibration includes adjusting model parameters (e.g., hydraulic conductivity or porosity) so that the output from the model reproduces observed field conditions. The calibrated model is then used to make predictions of future conditions.

At mine sites, much of the modeling performed is "forward" modeling, or modeling of conditions that do not yet exist. In the case of pit lakes, steady-state water quality and quantity conditions may not exist for hundreds of years, yet predictions about the quality of pit water are often required for regulatory purposes. Even though "final" water quality in pit lakes and other receptors may not develop for decades to centuries, water quality at other similar mines can be used to estimate the degree of uncertainty in the prediction.

Figure 3.1 depicts a mine site, pathways, and receptors and shows where hydrologic and geochemical models can be used at mine sites. More information on the methods and models used to predict water quality at hardrock mine sites can be found in the companion study to this report Predicting *Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art* (Maest et al., 2005).

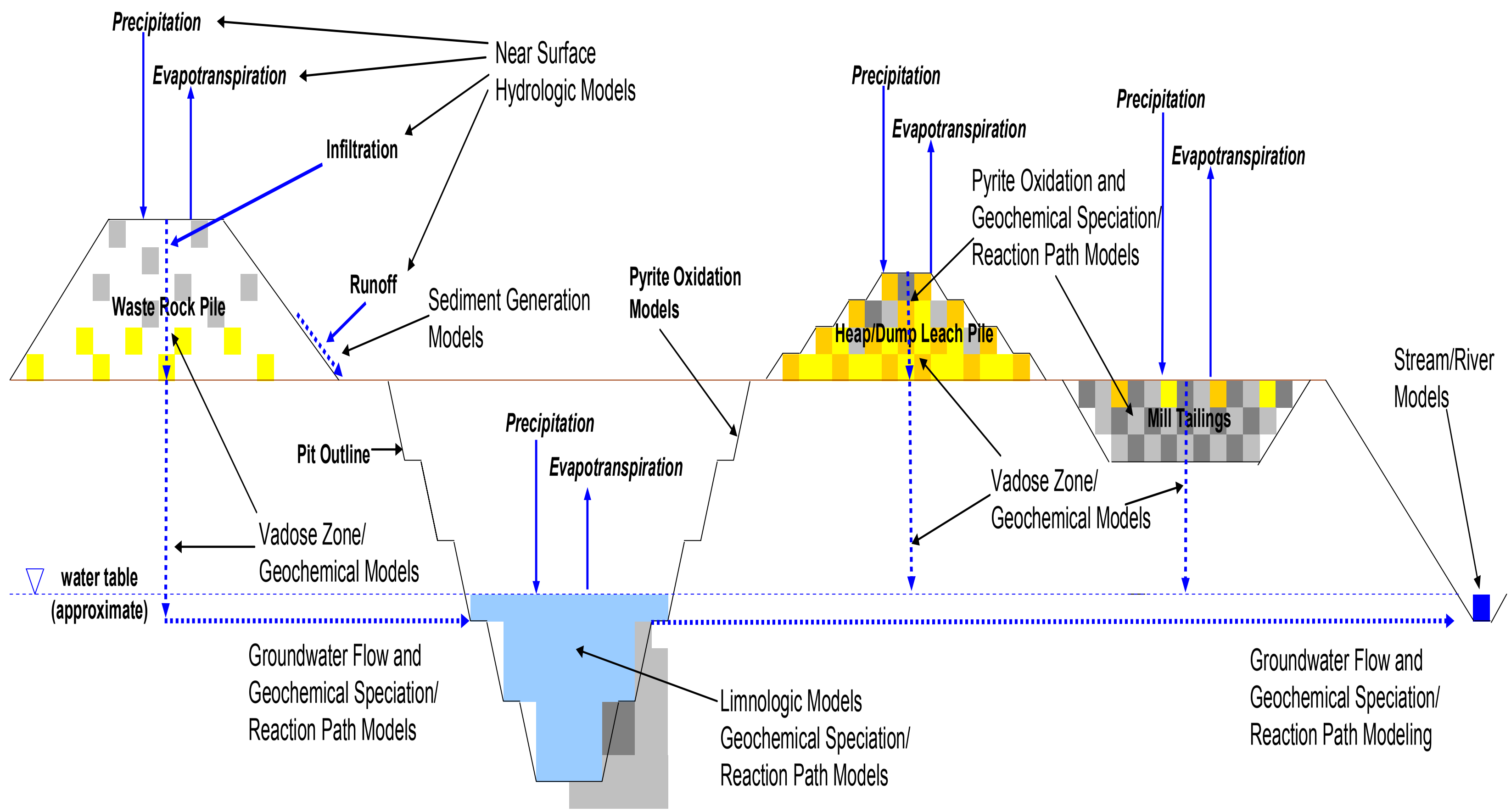

Figure 3.1. A mine site conceptual model with pathways and opportunities for hydrologic and geochemical modeling.

4. IDENTIFICATION OF MAJOR MINES SUBJECT TO NEPA

This section identifies the major hardrock mines in the United States and describes their location, commodity, extraction and processing methods (e.g., underground, open pit), operational status (e.g., operating, closed), extent of physical disturbance, financial assurance amounts, water discharge information under the Clean Water Act, and whether they are subject to the requirements of NEPA. The subset of the mines that is subject to NEPA is described separately, and it is these mines that form the basis of the main analysis in this report. A statistical breakdown is also provided for mines subject to NEPA in terms of NEPA authority (federal agency lead or state agency) and new and subsequent project permitting information. Information on the larger set of major mines and the mines subject to NEPA is contained in a database and Appendix A (database and appendices available at www/kuipersassoc.com or http://www.mineralpolicy.org/publications_welcome.cfm).

4.1. MAJOR MINES

This section describes the method and approach for identifying major mines subject to NEPA and discusses information described above for all mines, mines subject to NEPA, and mines for which EISs were obtained and reviewed in detail.

4.1.1. METHOD AND APPROACH

In order to identify a manageable data set and because they inherently receive the most interest, this study is focused on major hardrock mines. Major mines are defined as those meeting the following criteria:

- disturbance area of over 100 acres and financial assurance amount of over $250,000
- or, financial assurance amount over $1,000,000 alone
- or, cumulative production (1975 to current) of greater than 100,000 ounces of gold, 100,000,000 pounds of copper or the equivalent economic value for other metals

Kuipers (2000) identifies the disturbed area and financial assurance amounts for major mines with financial assurance amounts of over $250,000. In addition, production and other data from Randol (1991, 1995, 1999) and Infomine (2004) were used in establishing the list of major mines for this study.

Information from Kuipers (2000) was initially updated with current disturbance and financial assurance information readily available from regulatory sources (agency websites and publications). Most available information was unchanged from 2000 with the exception of significant updated information from Montana and New Mexico.

Production information was difficult to obtain, although some limited information was available from Randol and Infomine as well as from individual mine sources. The U.S. Geological Survey's Mineral Availability System/ Mineral Industry Locater System (MAS/MILS) is in the process of being overhauled and was unavailable to this study, although the use of coding to protect proprietary data makes the database of limited value to this study. Some mines that could be considered "major" may not meet the above criteria or may not have been included in this list due to the lack of available information.

One hundred eighty three (183) mines in the U.S. were identified as meeting the "major mine" criteria - in terms of meeting minimum disturbance areas and financial assurance or production criteria - and compiled in the Major Mine database. Table 4.1 identifies the major hardrock mines operating from 1975 to present and shows their location, commodity and operational status. Even though the mines subject to NEPA are not discussed until Section 4.2, the mines subject to NEPA and mines reviewed in detail (mines for which EISs were obtained and reviewed) are also identified in Table 4.1. As indicated in the table, for the purposes of this study some mines were combined and are counted as one mine (e.g., Zortman and Landusky, Paradise Peak/Ketchup Flat).

Table 4.1. General Information for Major Hardrock Metals Mines in U.S. Operating from 1975 to Present

Name	State	Commodity	Status	NEPA or State Equivalent Eligibility	Federal Agency and/or State	NEPA Documents Obtained
AJ Project	AK	Au	Withdrawn	Yes	EPA	Yes
Fort Knox	AK	Au	Operating	Yes	COE	Yes
Greens Creek	AK	Au, Ag, Pb, Zn	Operating	Yes	FS	Yes
Illinois Creek	AK	Au, Ag	Operating			
Kensington Project	AK	Au	In construction	Yes	FS	Yes
Pogo Project	AK	Au	Operating	Yes	COE, EPA	Yes
Red Dog	AK	Ag, Pb, Zn	Operating	Yes	COE, EPA	Yes
True North	AK	Au	Operating	Yes	COE	Yes
Ajo	AZ	Cu, Mo	Closed			
Bagdad	AZ	Cu, Mo	Operating	Yes	BLM	Yes
Carlotta	AZ	Cu	Permitting	Yes	FS	Yes
Cyprus Tohono	AZ	Cu	Closed	Yes	Indian Lands	Yes
Hayden	AZ	Ag, Cu	Operating			
Miami - PD	AZ	Ag, Cu	Operating	Yes	BLM, FS	Yes
Miami - BHP	AZ	Cu	Operating			
Mineral Park	AZ	Cu	Operating	Yes	BLM	
Mission	AZ	Ag, Cu	Operating	Yes	Indian Lands	Yes
Morenci	AZ	Cu	Operating	Yes	BLM	Yes
Pinto Valley	AZ	Cu, Mo	Closed			
Ray	AZ	Ag, Cu	Operating	Yes	BLM	Yes
Safford (Dos Pobres/San Juan)	AZ	Cu	Permitting	Yes	BLM	Yes
Sanchez	AZ	Cu	Withdrawn	Yes	BLM	Yes
San Manuel	AZ	Au, Ag, Cu, Mo	Closed			
Sierrita	AZ	Cu, Mo	Operating	Yes	BLM	
Silver Bell	AZ	Cu	Operating			
Superior	AZ	Cu	Closed			
Twin Buttes	AZ	Cu, Mo	Closed	Yes	BLM	
Yarnell	AZ	Au	Withdrawn	Yes	BLM	Yes
American Girl (Cargo Muchaco, Oro Cruz)	CA	Au, Ag	Closed	Yes	BLM	Yes
Briggs	CA	Au	Operating	Yes	BLM	Yes
Cactus Gold (Shumake)	CA	Au, Ag	Closed	Yes		
Castle Mountain	CA	Au, Ag	Closed	Yes	BLM	Yes
Carson Hill	CA	Au, Ag	Closed			
Gray Eagle	CA	Au, Ag, Cu, Zn	Closed			
Hayden Hill	CA	Au, Ag	Closed	Yes	BLM, FS	
Imperial	CA	Au	Permitting	Yes	BLM	
Jamestown (California Gold)	CA	Au	Closed	Yes		Yes
McLaughlin	CA	Au	Closed	Yes	BLM	Yes

Table 4.1. General Information for Major Hardrock Metals Mines in U.S. Operating from 1975 to Present (continued)

Name	State	Commodity	Status	NEPA or State Equivalent Eligibility	Federal Agency and/or State	NEPA Documents Obtained
Mesquite	CA	Au, Ag	Operating	Yes	BLM	Yes
Picacho	CA	Au	Closed	Yes		
Rand	CA	Au, Ag	Operating	Yes		Yes
Royal Mountain King	CA	Au, Ag	Closed	Yes		Yes
Soledad Mountain	CA	Au, Ag	Closed	Yes	BLM	
Climax	CO	Mo	Closed			
Cresson	CO	Au	Operating			
Empire	CO	Au, Ag	Closed			
Henderson	CO	Mo	Operating			
Pride of the West	CO	Au, Ag	Closed			
San Luis	CO	Au, Ag	Closed			
Summitville	CO	Au, Ag	Closed			
Sunnyside	CO	Au, Ag, Pb, Zn	Closed			
Victor	CO	Au	Operating			
Beartrack	ID	Au, Ag	Closed	Yes	FS	Yes
Black Pine	ID	Au, Ag	Closed	Yes	BLM, FS	Yes
Champagne	ID	Au, Ag	Closed			
Coeur	ID	Ag, Cu	Closed			
Galena	ID	Ag, Cu	Operating			
DeLamar	ID	Au, Ag	Closed			
Sunbeam	ID	Au	Closed	Yes	FS	Yes
Grouse Creek	ID	Au, Ag	Closed	Yes	FS	Yes
Lucky Friday	ID	Ag, Pb, Zn	Operating			
Stibnite	ID	Au, Ag	Closed	Yes	FS	Yes
Stone Cabin	ID	Au, Ag	Closed	Yes	BLM	Yes
Thompson Creek	ID	Mo	Operating	Yes	BLM, FS	Yes
Thunder Mountain	ID	Au	Closed			
Yellow Pine	ID	Au, Ag	Closed		FS	
White Pine	MI	Cu	Closed			
Basin Creek	MT	Au, Ag	Closed	Yes	FS	Yes
Beal Mountain	MT	Au, Ag	Closed	Yes	FS	Yes
Black Pine	MT	Au, Ag, Cu	Closed	Yes	FS	Yes
Continental	MT	Au, Ag, Cu, Mo	Operating	Yes		
Diamond Hill	MT	Au	Closed	Yes		
East Boulder	MT	PGM	Operating	Yes	FS	Yes
Golden Sunlight	MT	Au	Operating	Yes	BLM	Yes
Kendall	MT	Au, Ag	Closed	Yes	BLM	Yes
Mineral Hill	MT	Au, Ag	Closed	Yes	FS	Yes
Montana Tunnels	MT	Au, Ag, Pb, Zn	Operating	Yes		Yes
Montanore	MT	Ag, Cu	Withdrawn	Yes	FS	Yes
Rock Creek	MT	Ag, Cu	Permitting	Yes	FS	Yes
Stillwater	MT	PGM	Operating	Yes	FS	Yes

Table 4.1. General Information for Major Hardrock Metals Mines in U.S. Operating from 1975 to Present (continued)

Name	State	Commodity	Status	NEPA or State Equivalent Eligibility	Federal Agency and/or State	NEPA Documents Obtained
Troy	MT	Ag, Cu	Closed	Yes	FS	Yes
Zortman and Landusky	MT	Au, Ag	Closed	Yes	BLM	Yes
Alligator Ridge	NV	Au, Ag	Closed	Yes	BLM	
Aurora Partnership (Mine)	NV	Au, Ag	Closed	Yes	FS	Yes
Austin Gold Venture	NV	Au, Ag	Closed	Yes	FS	Yes
Bald Mountain	NV	Au, Ag	Operating	Yes	BLM	Yes
Horseshoe/Galaxy	NV	Au	Closed			
Battle Mountain Complex (Reona, Copper Basin, Copper Canyon, Iron Canyon, Shoshone-Eureka Phoenix)	NV	Au, Ag	Operating	Yes	BLM	Yes
Big Springs	NV	Au, Ag	Operating	Yes	FS	Yes
Blue Star (Genesis)	NV	Au, Ag	Operating	Yes	BLM	
Bootstrap/Capstone/Tara	NV	Au, Ag	Operating	Yes	BLM	
Borealis	NV	Au, Ag	Closed	Yes	FS	
Buckhorn	NV	Au, Ag	Closed	Yes	BLM	
Bullfrog	NV	Au, Ag	Closed	Yes	BLM	
Candelaria	NV	Au, Ag	Closed	Yes	BLM	
Carlin Mine/Mill # 1	NV	Au, Ag	Operating	Yes	BLM	
Casino/Winrock	NV	Au, Ag	Closed	Yes	BLM	
Rochester	NV	Au, Ag	Operating	Yes	BLM	Yes
Copper Leach Project (Equitorial Tonopah)	NV	Cu	Closed	Yes	BLM	
Cortez	NV	Au, Ag	Operating	Yes	BLM	Yes
Cortez Pipeline (South Pipeline)	NV	Au, Ag	Operating	Yes	BLM	Yes
County Line	NV	Au, Ag	Closed	Yes	BLM	
Crescent Pit	NV	Au, Ag	Operating	Yes	BLM	
Crowfoot/Lewis	NV	Au, Ag	Operating			
Daisy	NV	Au, Ag	Closed	Yes	BLM	
Dee	NV	Au, Ag	Closed	Yes	BLM	Yes
Denton Rawhide	NV	Au, Ag	Operating	Yes	BLM	
Easy Junior	NV	Au, Ag	Closed	Yes	BLM	
Elder Creek	NV	Au, Ag	Closed	Yes	BLM	
Florida Canyon	NV	Au, Ag	Operating	Yes	BLM	Yes
Fondaway Canyon	NV	Au, Ag	Closed	Yes	BLM	
Getchell	NV	Au, Ag	Operating			
Gold Acres	NV	Au, Ag	Operating	Yes	BLM	
Gold Bar	NV	Au, Ag	Closed	Yes	BLM	
Gold Quarry/Maggie Creek	NV	Au, Ag	Operating	Yes	BLM	Yes
Golden Eagle	NV	Au, Ag	Closed	Yes	BLM	

Table 4.1. General Information for Major Hardrock Metals Mines in U.S. Operating from 1975 to Present (continued)

Name	State	Commodity	Status	NEPA or State Equivalent Eligibility	Federal Agency and/or State	NEPA Documents Obtained
Goldfield	NV	Au, Ag	Operating	Yes	BLM	
Goldstrike (Betze)	NV	Au, Ag	Operating	Yes	BLM	Yes
Griffon	NV	Au, Ag	Closed	Yes	FS	Yes
Ivanhoe/Hollister	NV	Au, Ag	Operating	Yes	BLM	
Jerritt Canyon	NV	Au, Ag	Operating	Yes	FS	Yes
Dash	NV	Au, Ag	Operating	Yes	FS	Yes
Kinsley Mountain	NV	Au, Ag	Closed	Yes	BLM	
Leeville	NV	Au, Ag	Operating	Yes	BLM	Yes
Lone Tree	NV	Au, Ag	Operating	Yes	BLM	Yes
Manhattan	NV	Au, Ag	Closed	Yes	BLM, FS	
Marigold	NV	Au, Ag	Closed	Yes	BLM	Yes
McCoy/Cove	NV	Au, Ag	Closed	Yes	BLM	
Meikle	NV	Au, Ag	Operating	Yes	BLM	
Mineral Ridge	NV	Au, Ag	Operating	Yes	BLM	
Mount Hamilton	NV	Au, Ag	Closed	Yes	FS	
Mule Canyon	NV	Au, Ag	Operating	Yes	BLM	Yes
North Area Leach	NV	Au, Ag	Operating			
Northumberland	NV	Au, Ag	Closed	Yes	BLM, FS	
Olinghouse	NV	Au, Ag	Closed	Yes	BLM	Yes
Paradise Peak/Ketchup Flat	NV	Au, Ag	Closed	Yes	BLM	
Pete	NV	Au	Operating	Yes	BLM	Yes
Pinson	NV	Au, Ag	Closed	Yes	BLM	
Preble	NV	Au, Ag	Closed	Yes	BLM	
Post/Mill # 4	NV	Au, Ag	Operating			
Rain	NV	Au, Ag	Operating	Yes	BLM	Yes
Robinson (Ruth)	NV	Au, Cu	Operating	Yes	BLM	Yes
Rosebud	NV	Au, Ag	Closed	Yes	BLM	
Round Mountain	NV	Au, Ag	Operating	Yes	BLM, FS	Yes
Ruby Hill	NV	Au, Ag	Operating	Yes	BLM	Yes
Santa Fe/Calvada	NV	Au, Ag	Closed	Yes	BLM	
Sleeper	NV	Au, Ag	Closed	Yes	BLM	
Sterling JV	NV	Au, Ag	Operating	Yes	BLM	
Talapoosa	NV	Au, Ag	Withdrawn	Yes	BLM	
Tonkin Springs	NV	Au, Ag	Closed	Yes	BLM	
Trenton Canyon	NV	Au, Ag	Operating	Yes	BLM	Yes
Triplet Gulch/Robertson	NV	Au, Ag	Closed	Yes	BLM	
Twin Creeks	NV	Au, Ag	Operating	Yes	BLM	Yes
Wind Mountain	NV	Au, Ag	Closed	Yes	BLM	
Yankee	NV	Au, Ag	Closed	Yes	BLM	
Yerington	NV	Cu	Closed	Yes	BLM	
Chino	NM	Cu	Operating		BLM	
Cobre (Continental Pit)	NM	Cu	Closed	Yes	BLM	
Copper Flat	NM	Cu	Closed	Yes	BLM	Yes

Table 4.1. General Information for Major Hardrock Metals Mines in U.S. Operating from 1975 to Present (continued)

Name	State	Commodity	Status	NEPA or State Equivalent Eligibility	Federal Agency and/or State	NEPA Documents Obtained
Cunningham Hill	NM	Au, Ag	Closed			
Questa	NM	Mo	Operating			
Tyrone	NM	Cu	Operating			
Tyrone - Little Rock pit	NM	Cu	Closed	Yes	BLM, FS	Yes
Ridgeway	SC	Au, Ag	Closed			
Brewer	SC	Au	Closed			
Barite Hill	SC	Au	Closed			
Gilt Edge (Anchor Hill)	SD	Au, Ag	Closed	Yes	FS	Yes
Golden Reward	SD	Au, Ag	Closed			
Homestake	SD	Au, Ag	Closed			
Richmond Hill	SD	Au, Ag	Closed			
Wharf	SD	Au, Ag	Operating			
Barneys Canyon	UT	Au, Ag	Operating			
Bingham Canyon - Bingham Pit Fourth Line Expansion Modernization Project Tailing Modernization	UT	Au, Ag, Cu, Mo	Operating			
Drum Mine	UT	Au, Ag	Closed	Yes	BLM	Yes
Escalante Silver	UT	Ag	Closed	Yes	BLM	Yes
Goldstrike Project	UT	Au, Ag	Closed			
Lisbon Valley Copper	UT	Cu	Operating	Yes	BLM	Yes
Mercur Mine	UT	Au, Ag	Closed	Yes	BLM	Yes
Cannon	WA	Au, Ag	Closed	Yes		
Crown Jewel (Buckhorn Mountain)	WA	Au	Permitting	Yes	BLM, FS	
Kettle River/Lamefoot/K2	WA	Au, Ag	Closed	Yes	FS	
Pend Oreille	WA	Pb, Zn	Operating	Yes		
Flambeau (Ladysmith)	WI	Pb, Zn	Closed	Yes		Yes

Table 4.2 contains summary statistics on the information collected for the modern-era (i.e., in operation since 1975) major hardrock mines including location, commodity produced, extraction and processing methods, and operational status. Ownership information was also collected but was not analyzed in this report. The gross statistical data for the major hardrock metals mines in the U.S. was compiled and is summarized and discussed in the following sections. In addition, Appendix A provides a detailed breakdown of the statistical data by state and federal agency.

4.1.2. LOCATION

The 183 modern-era major hardrock metals mines identified are located in 14 states (five major mines were identified in three eastern states, and the remainder were in the western U.S.).

Table 4.2. General Information for Major Hardrock Mines

Feature		All Major Mines	
		Number	%
States	Alaska	8	4.4%
	Arizona	20	10.9%
	California	15	8.2%
	Colorado	9	4.9%
	Idaho	14	7.7%
	Michigan	1	0.5%
	Montana	15	8.2%
	Nevada	74	40.4%
	New Mexico	7	3.8%
	South Carolina	3	1.6%
	South Dakota	5	2.7%
	Utah	7	3.8%
	Washington	4	2.2%
	Wisconsin	1	0.5%
Commodity	Primary Gold	23	12.6%
	Primary Silver	13	7.1%
	Gold and Silver	115	62.8%
	Copper	30	16.4%
	Copper and Molybdenum	8	4.4%
	Molybdenum	4	2.2%
	Lead and Zinc	7	3.8%
	Platinum Group	2	1.1%
Operation Type	Underground	27	14.8%
	Open Pit	132	72.1%
	Underground + Open Pit	22	12.0%
	Heap or Vat Leach	120	65.6%
	Flotation and Gravity	44	24.0%
	Dump Leach (SX/EW)	22	12.0%
	Heap Leach	72	39.3%
	Vat Leach	17	9.3%
	Heap Leach and Vat Leach	31	16.9%
	Smelter	6	3.3%
Status	Operating	82	44.8%
	Closed	89	48.6%
	In Construction	1	0.5%
	Permitting	7	3.8%
	Withdrawn	4	2.2%

As indicated in Table 4.2, 74 (40%) of the major mines are located in Nevada. Nevada's modern-era mines are almost all primary gold and silver mines developed and operated since 1975, although a few notable historic gold and copper mining operations are present in the state.

Arizona, California and Montana are also significant mining states with 20 (11%), 15 (8%) and 15 (8%) respectively located in those states. Arizona's modern-era mines, on the other hand, are nearly all copper mines that were developed and operated from the early 1900s to the 1960s with many still operating. Despite California's illustrious mining history, nearly all its modern-era major mines were developed and operated since 1975. In the same manner, Montana's modern-era major mines were developed and operated since 1975 with the exception of the ongoing copper operations at Butte.

The states of Idaho, Colorado, New Mexico, Utah, Alaska and South Dakota respectively have 13 (8%), nine (5%), seven (4%), seven (4%), eight (4%) and five (3%) of the major mines. Idaho, Colorado, New Mexico and Utah have both historic and new mines. Alaska's and South Dakota's modern-era mines have all been developed and operated since 1975, with the exception of the Homestake Mine located in South Dakota.

Three (2%) of the major mines are located in South Carolina, four (2%) in Washington and one (1%) each in Michigan and Wisconsin. The modern-era major mines in South Carolina, Washington and Wisconsin were all developed and operated since 1975, while the Michigan mine was an historic operation.

No major mines were located in other states. However, some mining was still being conducted in Missouri and Tennessee in 1975, but production at these mines since 1975 has been less than the production criteria identified for major mines included in this study.

4.1.3. COMMODITY

The 183 modern-era major hardrock mines produce gold, silver, copper, molybdenum, lead, zinc and platinum group minerals (platinum and palladium).

As indicated in Table 4.2, two-thirds or 115 (63%) of the mines were identified as gold and silver mines. When combined with the 23 (13%) mines identified as primary gold mines and 13 (7%) mines identified as primary silver mines, 151 (83%) of the modern-era major hardrock mines extract precious metals.

There are 30 (16%) modern-era mines that are primary copper mines, while eight (4%) produce both copper and molybdenum. Four (2%) mines are primary molybdenum mines. Seven (4%) modern-era mines produce lead and zinc, while two (1%) produce platinum group minerals. Some of the mines produce multiple commodities (e.g., gold, silver, lead, zinc); therefore, the number of mines identified in this section is greater than the 183 total mines.

4.1.4. EXTRACTION AND PROCESSING METHODS

The 183 modern-era major hardrock mines are operated by both open pit and underground extraction methods, and employ heap or vat leaching, flotation/gravity, and dump leaching processing methods.

As shown in Table 4.2, the majority of mines (132 or 72%) are operated by open pit methods only. Twenty-seven (15%) of the mines are operated solely by underground mining methods, and 22 (12%) of the mines are operated by combined underground and open pit methods. Following a boom in open pit mining, the trend for gold in particular has been toward underground mining as shallower resources are exploited.

As indicated in Table 4.2, cyanide leaching is the predominant method used for gold ore processing and is used at 120 (66%) of the major mines identified. Seventy-two (38%) of the operations rely on heap leaching processes, while 17 (9%) rely on vat leaching. Thirty-one (17%) use both heap leaching and vat leaching processing methods.

Dump leaching is used exclusively at copper mines, and is the process used at 22 (12%) of the major mines identified. Flotation and gravity processing were the primary process methods used at 44 (24%) of the mines identified.

Six (3%) of the major mines had smelters associated with their operations. These mines were all copper mines.

4.1.5. OPERATIONAL STATUS

As this study takes into account a nearly 30-year time span (1975 to present), many of the 183 mines identified will have operated and subsequently closed. As shown in Table 4.2, 82 (45%) of the mines operated during that period are still currently operating. Eighty-nine (49%) of the major mines that operated have closed during that period. Currently, only one (less than 1%) of the major mines is a new mine (Pogo, Alaska) and is in construction, while seven (4%) are in permitting. A significant number of the mines identified are expanding, but they are not specifically identified in this study.

4.1.6. DISTURBANCE AND FINANCIAL ASSURANCE

Reliable disturbance and financial assurance information is not readily available outside of the Kuipers (2000) study, which identified the disturbed areas and reclamation amounts for most modern-era major mines in this study. Updated information is not readily available, except for a limited number of mines in certain states. Information on actual or projected disturbed acres and financial assurance amounts was available for only 138 of the 183 major mines in this study.

The 138 mines have actually or are projected to disturb 262,308 acres in total and have an aggregate financial assurance amount of $1.8 billion. The average major mine disturbance area is 1,901 acres, and the average financial assurance amount is $13.2 million.

4.1.7. NPDES INFORMATION

As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Point sources are discrete conveyances such as pipes or other conveyances that discharge to surface waters. In most cases, the NPDES permit program is administered by authorized states, although it may also be administered by the EPA. Since its introduction in 1972, the NPDES permit program is responsible for significant improvements to our nation's water quality.

Of the 183 major modern-era mines identified in this study, 41 (23%) have NPDES permits according to the EPA's Enforcement History and Online (ECHO) database.[1] EPA classifies larger, more regulated facilities as *major* facilities and smaller facilities as *minor* facilities.[2] On that basis, EPA has classified 27 of the 41 NPDES permitted major mines as major facilities and 14 as minor facilities.

At least four other facilities were identified as having permitted discharges to surface water that were not identified in the search of the ECHO database.

4.2. MAJOR MINES WITH NEPA EIS ANALYSIS

A subset of the 183 identified major modern-era mines is subject to NEPA regulation. For a hardrock mine to be subject to the NEPA process, the six independent requirements are:

- location on federal land administered by the USDA Forest Service
- location on federal land administered by the USDI Bureau of Land Management;
- requirement for new source NPDES permit from EPA
- requirement for 404 wetlands permit from the Army Corp of Engineers (ACE)
- location on Indian Lands administered by the BIA
- state mandated requirement for NEPA equivalent process

[1] http://www.epa.gov/echo/

[2] **"Minor discharge"** means a discharge of wastewater which has a total volume of less than 50,000 gallons on every day of the year, does not closely affect the waters of another state and is not identified by the Department, the Regional Administrator or by the Administrator of EPA in regulations issued by him pursuant to Section 307(a) of the Federal Act, as a discharge which is not a minor discharge, except that in the case of a discharge of less than 50,000 gallons on any day of the year which represents one or two or more discharges from a single person, which in total exceeds 50,000 gallons on any day of the year, then no discharge from the facility is a minor discharge.

Of the 183 major modern-era mines identified, 137 (77%). meet the above requirements and are subject to the NEPA process. Of the 137 modern-era hardrock mines subject to NEPA analysis, the following criteria were the requirements used to determine their eligibility for NEPA:

- 93 (68%) are located on BLM administered lands
- 34 (25%) are located on Forest Service administered lands
- nine (7%) are located on both BLM and Forest Service administered lands
- five (4%) required 404 wetlands permits from the COE invoking NEPA
- three (2%) required NPDES permits from EPA invoking NEPA
- two (1%) are located on Indian Lands invoking NEPA
- 23 (19%) are located in states (California, Montana, Wisconsin) that have NEPA requirements
- 17 (14%) require both NEPA for federal purposes and are located in states that have NEPA requirements
- six (5%) require NEPA to meet state requirements only

Table 4.3 summarizes the general information collected for the 137 major hardrock mines subject to NEPA, including location, commodity produced, extraction and processing methods, and operational status. Statistical information for the major hardrock mines subject to NEPA in the U.S. was compiled and is summarized and discussed in the following sections with more detailed information by state and federal agency available in Appendix A.

4.2.1. LOCATION

The 137 modern-era major hardrock mines identified as subject to NEPA are located in 11 states (one major mine subject to NEPA was located in Wisconsin, and the remaining mines are in the western U.S.). States that have major mines but do not have mines subject to NEPA include: Colorado, Michigan and South Carolina.

As indicated in Table 4.3, 69 (50%) of the major mines subject to NEPA are located in Nevada. California, Montana and Arizona are also significant with 13 (10%), 15 (11%) and 13 (10%) of the major mines subject to NEPA respectively located in those states. The states of Idaho, Alaska and Utah respectively have six (4%), seven (5%), and four (3%) of the major mines subject to NEPA. Four (3%) are located in New Mexico, while one (1%) each is located in South Dakota and Wisconsin. In many cases, historically operated mines have succeeded in patenting or otherwise removing land from the public domain and result in no required NEPA analysis, except in states that require NEPA analysis separately. Colorado is notable in this regard, as it historically and presently hosts a significant mining industry, but although nine modern-era major hardrock mines were identified in the state, none were subject to NEPA.

4.2.2. COMMODITY

The 137 major hardrock mines subject to NEPA produce gold, silver, copper, molybdenum, lead, zinc and platinum group minerals (platinum and palladium).

As indicated in Table 4.3, over two-thirds or 90 (66%) of the mines were identified as gold and silver mines. When combined with the 17 (13%) mines identified as primary gold mines and nine (7%) mines identified as primary silver mines, 116 (85%) of the modern-era major hardrock mines subject to NEPA extract precious metals.

There are 21 (15%) modern-era mines subject to NEPA that are primary copper mines, while four (3%) mines produce both copper and molybdenum. Only one (1%) mine is a primary molybdenum mine. Five (4%) modern-era mines subject to NEPA produce lead and zinc, while two (2%) of the mines produce platinum group minerals. Some of the mines produce multiple commodities (e.g., gold, silver, lead, zinc) so the numbers of mines identified in this section total greater than the 137 total mines subject to NEPA.

4.2.3. EXTRACTION AND PROCESSING METHODS

The 137 major hardrock mines subject to NEPA are operated by both open pit and underground mining methods, and employ heap or vat leaching, flotation/gravity, and dump leaching processing methods.

Table 4.3. General Information for Major Mines Subject to NEPA

Feature		All Major Mines	
		Number	%
States	Alaska	7	5.1%
	Arizona	13	9.5%
	California	13	9.5%
	Idaho	6	4.4%
	Montana	15	10.9%
	Nevada	69	50.4%
	New Mexico	4	2.9%
	South Dakota	1	0.7%
	Utah	4	2.9%
	Washington	4	2.9%
	Wisconsin	1	0.7%
Commodity	Primary Gold	17	12.4%
	Primary Silver	9	6.6%
	Gold and Silver	90	65.7%
	Copper	21	15.3%
	Copper and Molybdenum	4	2.9%
	Molybdenum	1	0.7%
	Lead and Zinc	5	3.6%
	Platinum Group	2	1.5%
Operation Type	Underground	19	13.9%
	Open Pit	104	75.9%
	Underground + Open Pit	14	10.2%
	Heap or Vat Leach	95	69.3%
	Flotation and Gravity	28	20.4%
	Dump Leach (SX/EW)	15	10.9%
	Heap Leach	53	38.7%
	Vat Leach	14	10.2%
	Heap Leach and Vat Leach	28	20.4%
	Smelter	2	1.5%
Status	Operating	64	46.7%
	Closed	61	44.5%
	In Construction	1	0.7%
	Permitting	6	4.4%
	Withdrawn	5	3.6%

As shown in Table 4.3, the majority of mines 104 (76%) are operated by open pit methods only. Nineteen (14%) of the mines are operated solely by underground mining methods. Fourteen (10%) of the mines are operated by combined underground and open pit methods.

As indicated in Table 4.3, cyanide leaching is the predominant method used for gold ore processing and is used at 95 (69%) of the major mines subject to NEPA identified. Fifty-three (39%) of the operations rely on heap leaching processes, while 14 (10%) rely on vat leaching. Twenty-eight (20%) of these mines use both heap leaching and vat leaching processing methods.

Dump leaching is used exclusively at copper mines, and is the process used at 15 (11%) of the major mines subject to NEPA identified. Flotation and gravity processing were the primary process methods used at 28 (20%) of the mines subject to NEPA identified.

Two (2%) of the major mines subject to NEPA had smelters associated with their operations. These mines were both copper mines.

4.2.4. OPERATIONAL STATUS

As this study takes into account a time span of approximately 30 years (1975 to present), many of the 137 major mines subject to NEPA identified will have operated and closed. As shown in Table 4.3, 64 (47%) of the mines subject to NEPA operated during that period are still currently operating. Sixty-one (45%) of the major mines subject to NEPA that operated have closed during that period. Currently, only one (less than 1%) new mine subject to NEPA (Pogo, Alaska) is in construction, while six (4%) are in permitting, and five (4%) were withdrawn from the permitting process.

4.3. COLLECTION OF EISS FOR MINES SUBJECT TO NEPA

EISs were performed at 82 (60%) of the 137 major mines subject to NEPA, either as part of new permitting actions or as part of later expansion or other subsequent actions. EAs only, based on agency regulatory findings of no significant impact, were performed at the remainder of the mines subject to NEPA. The EISs resulted from the following conditions or mine site actions:

- ten (7%) of the mines with EISs were in operation prior to NEPA enactment but had later EISs for expansion or other (e.g., land swap) purposes
- twenty (15%) out of 71 (51%) mines originally permitted as new operations with EAs had subsequent EISs related primarily to expansion proposals
- fifty-two (38%) of the mines subject to NEPA were originally permitted as new projects with EISs

EISs and EAs were obtained by writing, emailing, and/or calling state and federal agencies, including the BLM, USDA Forest Service, and tribal agencies, as well as conducting library searches. Some agencies were quick to respond to our requests and provided information promptly. Most agencies required a written Freedom of Information Act (FOIA) request letter, and most were honored within 30 days of receipt, while others took months to respond. There were several agencies that denied our FOIA request for a fee waiver and charged copying fees for documents. Due to the cost of copying, some documents were not acquired. There were occasions for older mines where the agencies no longer had copies of the NEPA documents because they had been “loaned out” and never returned or older documents were “thrown out” to make room for new projects. The process of obtaining NEPA documents took approximately 16 months and involved numerous follow-up calls, written, and email contact.

Of the 137 major mines subject to NEPA, 71 mines had documents that were obtained and reviewed. A total of 104 NEPA documents, either EISs or EAs, were reviewed for the 71 mines. Table 4.4 identifies the 71 NEPA mines that were reviewed for this study and summarizes information on the location, commodity, extraction, processing methods and operational status for the 71 mines reviewed. The general statistical data for the major hardrock metals mines subject to NEPA reviewed in the U.S. are summarized and discussed in the following sections.

4.3.1. LOCATION

The 71 modern-era major hardrock mines with EISs that were reviewed are located in 10 different states. One major mine is located in the mid-west (Wisconsin), seven are in Alaska, and the remaining mines are in the western contiguous U.S.

As indicated in Table 4.4, 24 (34%) of the major mines with EISs that were reviewed are located in Nevada. Arizona, California and Montana are also significant with eight (11%), eight (11%) and 13 (18%) respectively located in those states. The states of Idaho, New Mexico and Alaska respectively have six (9%), two (3%) and seven (10%). South Dakota, Utah and Wisconsin each have one (1%) of the major mines with reviewed EISs.

Table 4.4. General Information for Mines with Reviewed EISs

Feature		All Major Mines	
		Number	%
	Alaska	7	9.9%
	Arizona	8	11.3%
	California	8	11.3%
	Idaho	6	8.5%
	Montana	13	18.3%
	Nevada	24	33.8%
	New Mexico	2	2.8%
	South Dakota	1	1.4%
	Utah	1	1.4%
	Wisconsin	1	1.4%
Commodity	Primary Gold	14	19.7%
	Primary Silver	5	7.0%
	Gold and Silver	39	54.9%
	Copper	14	19.7%
	Copper and Molybdenum	1	1.4%
	Molybdenum	1	1.4%
	Lead and Zinc	4	5.6%
	Platinum Group	2	2.8%
Operation Type	Underground	13	18.3%
	Open Pit	51	71.8%
	Underground + Open Pit	7	9.9%
	Heap or Vat Leach	44	62.0%
	Flotation and Gravity	19	26.8%
	Dump Leach (SX/EW)	8	11.3%
	Heap Leach	18	25.4%
	Vat Leach	10	14.1%
	Heap Leach and Vat Leach	16	22.5%
	Smelter	1	1.4%
Status	Operating	35	49.3%
	Closed	26	36.6%
	In Construction	1	1.4%
	Permitting	5	7.0%
	Withdrawn	4	5.6%

4.3.2. COMMODITY

The 71 modern-era major hardrock mines with EISs that were reviewed produce gold, silver, copper, molybdenum, lead, zinc and platinum group minerals (platinum and palladium).

As indicated in Table 4.4, 39 (55%) of the mines were identified as gold and silver mines. When combined with the 14 (20%) mines identified as primary gold mines and five (7%) mines identified as primary silver mines, 58 (82%) of the modern-era major hardrock mines with reviewed EISs extract precious metals.

There are 14 (20%) modern-era mines with reviewed EISs that are primary copper mines, while one (1%) produces both copper and molybdenum. Only one (1%) is a primary molybdenum mine. Four (6%) of the mines produce lead and zinc, and two (3%) produce platinum group minerals. Some of the mines produce multiple commodities (e.g., gold, silver, lead, zinc); therefore, the numbers of mines identified in this section have a total greater than the 137 mines subject to NEPA.

4.3.3. EXTRACTION AND PROCESSING METHODS

The 71 modern-era major hardrock mines with EISs reviewed are operated by both open pit and underground mining methods, and employ heap or vat leaching, flotation/gravity, and dump leaching process methods.

As shown in Table 4.4, the majority of mines (51 or 72%) are operated by open pit methods only. Thirteen (18%) of the mines are operated solely by underground mining methods. Seven (10%) of the mines are operated by combined underground and open pit methods.

As indicated in Table 4.4, cyanide leaching is the predominant method used for gold ore processing and is used at 44 (62%) of the major mines with reviewed EISs. Eighteen (25%) of the operations rely on heap leaching processes, while 10 (14%) rely on vat leaching. Sixteen (23%) use both heap leaching and vat leaching processing methods.

4.3.4. OPERATIONAL STATUS

Many of the 71 mines with reviewed EISs have operated and subsequently closed during the 30-year time span (1975 to present) of this study. As shown in Table 4.4, 35 (49%) of the mines operated during that period are currently operating. Twenty-six (37%) of the major mines that operated have closed during that period. Currently, one (less than 1%) new mine (Pogo, Alaska) is in construction, while 5 (7%) are in permitting.

4.3.5. NPDES INFORMATION

According to the EPA's Enforcement History and Online (ECHO) database, 19 (27%) of the 71 major modern-era mines subject to NEPA reviewed in detail have NPDES permits. EPA classifies larger, more regulated facilities as *major* facilities and smaller ones as *minor* facilities. On that basis, EPA has classified nine of the 19 NPDES permitted major mines as major facilities and 10 as minor facilities.

At least one other major mine subject to NEPA was identified as having permitted discharges to surface water that were not identified in the search of the ECHO database.

4.4. COMPARISON OF MINE INFORMATION

A comparison of the statistical results for major mines, major mines subject to NEPA, and major mines subject to NEPA with EISs reviewed are provided in Table 4.5. The table shows that the various categories of mines are comparable and that the NEPA subject mines with EISs reviewed in detail are reasonably comparable to the major hardrock metals mines and NEPA subject mines based on general statistical information.

The hardrock mines in the United States are spread over 14 states, most of them in the western United States. The mines with reviewed EISs cover 10 states, excluding Colorado, Michigan, South Carolina, and Washington. Colorado, Michigan, and South Carolina have no mines subject to NEPA, so mines from these states were excluded from review based on the constraints of the study. The mines subject to NEPA with EISs reviewed in detail are similar to all major mines and all major mines subject to NEPA in terms of commodity type. The mines reviewed in detail have a somewhat larger representation of primary gold mines and copper mines, but a somewhat smaller percentage of combined gold and silver mines. In terms of extraction methods, the mines subject to NEPA with reviewed EISs have a somewhat higher proportion of underground mines compared to all major mines and all major mines subject to NEPA but are otherwise quite similar to the larger dataset. For processing methods, the mines subject to NEPA with reviewed EISs have a somewhat lower percentage of heap leach operations and a somewhat higher proportion of vat leach operations but are otherwise quite similar to the larger dataset. In terms of operational status, the mines subject to NEPA with EISs reviewed have a somewhat higher proportion of operating mines and a lower percentage of closed mines but are otherwise similar to the larger dataset. These differences will favor examination of the more modern mines in the United States.

Table 4.5. Comparison of Major Mines, Major Mines Subject to NEPA and Major Mines Subject to NEPA with EISs Reviewed in Detail

Feature		Major Mines	Major Mines Subject to NEPA	Major Mines Subject to NEPA with EISs Reviewed in Detail
		% of total mines in category		
States	Alaska	4.40%	5.10%	9.90%
	Arizona	10.90%	9.50%	11.30%
	California	8.20%	9.50%	11.30%
	Colorado	4.90%		
	Idaho	7.70%	4.40%	8.50%
	Michigan	0.50%		
	Montana	8.20%	10.90%	18.30%
	Nevada	40.40%	50.40%	32.40%
	New Mexico	3.80%	2.20%	2.80%
	South Carolina	1.60%		
	South Dakota	2.70%	0.70%	1.40%
	Utah	3.80%	2.90%	1.40%
	Washington	2.20%	2.90%	
	Wisconsin	0.50%	0.70%	1.40%
Commodity	Primary Gold	12.60%	12.40%	19.70%
	Primary Silver	7.10%	6.60%	7.00%
	Gold and Silver	62.80%	65.70%	54.90%
	Copper	16.40%	15.30%	19.70%
	Copper and Molybdenum	4.40%	2.90%	1.40%
	Molybdenum	2.20%	0.70%	1.40%
	Lead and Zinc	3.80%	3.60%	5.60%
	Platinum Group	1.10%	1.50%	2.80%
Operation Type	Underground	14.80%	13.90%	18.30%
	Open Pit	72.10%	75.90%	71.80%
	Underground + Open Pit	12.00%	10.20%	9.90%
	Heap or Vat Leach	65.60%	69.30%	62.00%
	Flotation and Gravity	24.00%	20.40%	26.80%
	Dump Leach (SX/EW)	12.00%	10.90%	11.30%
	Heap Leach	39.30%	38.70%	25.40%
	Vat Leach	9.30%	10.20%	14.10%
	Heap Leach and Vat Leach	16.90%	20.40%	22.50%
	Smelter	3.30%	1.50%	1.40%
Operational	Operating	44.80%	46.70%	49.30%
	Closed	48.60%	44.50%	36.60%
	In Construction	0.50%	0.70%	1.40%
	Permitting	3.80%	4.40%	7.00%
	Withdrawn	2.20%	3.60%	5.60%

5. WATER QUALITY PREDICTIONS INFORMATION

Information relevant to water quality predictions was collected by reviewing the available scientific and technical documentation for each of the 71 major mines where complete information in the form of EISs or EAs was available. The information collected consisted of the following elements:

- geology/mineralization
- climate
- hydrology
- field and lab tests performed
- constituents of concern identified
- predictive models used
- water quality impact potential
- mitigation
- predicted water quality impacts
- discharge information

Some of the elements contain sub-elements. For example, hydrology includes the sub-elements of surface water hydrology (proximity to surface water) and groundwater hydrology (depth to groundwater). For each type of information, a score was derived to characterize the element (e.g., geology/mineralization used six scores, including one for no information provided). The scoring allowed statistics to be performed on the information in the NEPA documents. All of the elements except for constituents of concern and mitigation have percentages that add to 100 percent. Because a given mine could have more than one type of constituent of concern (e.g., metals and metalloids and cyanide), scores will sum to greater than 100 percent. Similarly, a given mine could have more than one type of groundwater mitigation or surface water mitigation (e.g., source controls and monitoring and perpetual treatment), and scores will also sum to greater than 100 percent. Although a given mine could have conducted more than one type of field or laboratory geochemical characterization test, the scores were so that each mine had a unique score (e.g., one category is static testing only, and another is static, short-term leach, and kinetic testing).

In a number of instances, multiple EISs or EAs were reviewed for a given mine. For those mines, different approaches were used to concatenate the scores into one score per mine site. In general, the most environmentally conservative score was used as the bulk score for the mine. For example, for surface water proximity (a sub-element of hydrology), the score from the EIS that noted the closest proximity to surface water was used. The approach for concatenating scores from multiple EISs is described, where relevant, for each element and sub-element.

With the exception of the climate classifications, all scoring was based on information available in the EISs or EAs. If information or a subset of the information was not described in the EIS or EA, other additional sources of information to describe the element were not used. In this way, the scores reflect only the information that was considered by the regulators in the environmental review process.

5.1. SUMMARY OF RESULTS

The information summarized in this section was derived from the 71 mines reviewed for this study that were subject to the regulatory requirements of NEPA that resulted in water quality predictions. All information in this section was collected from the reviewed EISs or EAs and is a summary of or an exact replica or that information as it appeared in the document. In most cases, the information was scored to allow for statistical analysis. For mines with multiple EISs and/or EAs, only one final score was used in the tables and statistical analysis. In most cases, this was the most environmentally conservative score. For example, for groundwater depth, the score denoting the shallowest depth to groundwater was used, and for acid drainage potential, the score indicating the highest acid drainage potential was used.

Geology and mineralization information focused primarily on the geologic and mineralogical characteristics of the ore and the surrounding rock that would make mined materials more or less susceptible to acid drainage generation. The synopsis is only a generalized overview of all the rock types and mineralization present at the site, especially for rocks in the area of the ore deposit that will be mined. The major categories scored varied from low potential to create acid drainage to high potential to generate acidity with the following results:

- No/insufficient information available (23%)
- Low sulfide content, carbonate present or hosted in carbonate (10%)
- Low sulfide content, low carbonate content/carbonate not mentioned (7%)
- Sulfides present, carbonate or moderate to high NP rock present (33%)
- Sulfides present, no carbonates/carbonates not mentioned or associated with ore body (23%)
- High sulfide content, carbonates low/not present (3%)

Climate information gathered included general descriptions of climate type (i.e., arid, semi arid, coastal marine, northern, etc), precipitation data, and evaporation data. The climate - type descriptions in the NEPA documents varied substantially in detail and scope of coverage. The modified Köppen system was used to denote the major climate regions and their sub-classifications, and the results for the NEPA mines were with the following results:

- Dry/Arid Low and Middle Latitude Deserts (20%)
- Dry/Semi-Arid Middle Latitude Climates (35%)
- Humid Subtropical (4%)
- Marine West Coast (4%)
- Boreal Forest (28%)
- Continental (3%)
- Sub-Arctic (4%)

Hydrology information gathered included information on surface water proximity and depth to groundwater depth. Information on surface water proximity was classified as:

- No information provided (7%)
- Intermittent/ephemeral streams on site - perennial streams >1 mile away (26%)
- Intermittent/ephemeral streams on site - perennial streams <1 mile away (25%)
- Perennial streams on site (44%)

Depth to Groundwater information was classified as:

- No information provided (12%)
- Depth to groundwater > 200 feet (16%)
- Depth to groundwater < 200 but >50 feet (13%)
- Depth to groundwater 0 to 50 feet and/or springs on site (59%)

Laboratory and field geochemical testing methods information gathered focused on the main types of geochemical characterization tests used: static, short-term leach and kinetic testing, and fell into the following categories:

- No information (10%)
- Static testing only (13%)
- Short-term leach testing only (6%)
- Kinetic testing only (2%)
- Static and short-term leach testing (17%)
- Static and kinetic testing (16%)
- Short-term leach and kinetic testing (2%)
- Static, short-term leach, and kinetic testing (35%)

Constituents of concern (COC's) were identified in the EISs and included:
- None/insufficient information (16%)
- Metals (74%)
- Radionuclides (1%)
- Cyanide (23%)
- Metalloids, oxyanions (55%)
- Conventional pollutants (49%)

Predictive models were used in the EISs with the following frequency:
- No predictive models used (44%)
- Only water quantity predictive models used (26%)
- Only water quality predictive models used (2%)
- Both water quantity and water quality predictive models used (29%)

This report distinguishes between potential and predicted water quality impacts. A potential water quality impact is one that could occur if mitigation are not in place, and predicted water quality impacts are those that threaten water quality even after mitigation are in place. Potential water quality impacts are related to the inherent characteristics of the mine location or of the mined materials, such as acid drainage and contaminant leaching, climate, and proximity to water resources. Potential water quality impacts are described in the NEPA documents. The elements of water quality impact potential included acid drainage potential, contaminant leaching potential, and potential groundwater, surface water, and pit water impacts.

Acid drainage potential was summarized and scored as follows:
- No information available (9%)
- Low acid drainage potential (58%)
- Moderate acid drainage potential (6%)
- High acid drainage potential (27%)

Contaminant leaching potential was summarized and scored as follows:
- No information available (22%)
- Low contaminant leaching potential (leachate does not exceed water quality standards) (32%)
- Moderate potential for elevated contaminant concentrations (leachate exceeds water quality standards by 1-10 times) (30%)
- High potential for elevated contaminant concentrations (leachate exceeds water quality standards by over 10 times) (17%)

Groundwater impact potential was summarized and scored as follows:
- No information available (20%)
- Low groundwater quality impacts (< relevant standards) (25%)
- Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) (48%)
- High groundwater quality impacts (>10 times relevant standards) (7%)

Surface water impact potential was summarized and scored as follows:
- No information available (23%)
- Low surface water quality impacts (< relevant standards) (33%)
- Moderate surface water quality impacts (≥ and up to 10 times relevant standards) (41%)
- High surface water quality impacts (>10 times relevant standards) (3%)

Pit water impact potential was summarized and scored as follows:

- No information available (22%)
- Low pit water quality impacts (water quality similar to surrounding groundwater or < relevant standards) (12%)
- Moderate pit water quality impacts (≥ and up to 10 times relevant standards) (17%)
- High pit water quality impacts (>10 times water quality standards) (14%)
- No pit lake or water expected (pit above water table or no pit) (35%)

EISs analyze and may require mitigation to address potential water quality impacts that are identified. Mitigation measures are commonly designed for the protection of groundwater and surface water resources, and may address pit water quality (depending on state requirements). Water-quality mitigation identified in the EISs fell into groundwater, surface water, and pit water measures. For mines that proposed treatment as part of the mitigation measures, the type of treatment was also categorized and scored.

Proposed groundwater mitigation were summarized and scored as follows (total exceeds 100% as some mines employ multiple mitigation):

- No information available or no mitigation identified (17%);
- Groundwater monitoring or characterization of mined materials (48%);
- Source controls without treatment (liners, leak detection systems, run on/off controls, caps/covers, adit plugging) (71%);
- Groundwater/leachate capture with treatment (38%);
- In-perpetuity groundwater capture and/or treatment; long-term mitigation fund (4%);
- Liming, blending, segregation, etc. of potentially acid-generating (PAG) material (19%).

Proposed surface water mitigation were summarized and scored as follows:

- No information available or no mitigation identified (15%);
- Surface water monitoring (14%);
- Stormwater, sediment, or erosion controls (68%);
- Source controls not involving capture of water (including liners, adit plugging, caps/covers, leak detection systems, spill prevention measures, and liming/blending/segregating of PAG materials) (30%);
- Surface water/leachate capture and/or treatment (including settling, land application, routing of water, seepage collection) (30%);
- Perpetual surface water capture and/or treatment (3%);
- Surface water augmentation or replacement (3%).

Proposed pit water mitigation were summarized and scored as follows:

- No information provided or none identified (25%);
- Pit lake monitoring (9%);
- Pit lake prevention (backfill, pumping, stormwater diversion, use in mine operation) (41%);
- Treatment of pit water or backfill amendment (e.g., lime addition) (9%);
- Not applicable: no pit lake will form (underground mine or pit above water table) (33%);
- Contingency or research fund for pit lake, adaptive management (3%).

Proposed water treatment measures were summarized and scored as follows:

- No information provided or no water treatment measures identified (70%);
- Solids or sediment settling ponds (9%);
- Water treatment for cyanide (9%);
- Water treatment for metals and/or acid drainage (22%);
- Water treatment using non-conventional approaches (15%);
- Perpetual water treatment (6%).

A predicted water quality impact is one that could occur after mitigation is in place. It is these predicted, or post-mitigation, impacts that are considered by regulators when evaluating whether a proposed mine will meet applicable water quality standards.

Predicted groundwater quality impacts were summarized and scored as follows:

- No information available (9%)
- Low groundwater quality impacts (< relevant standards) (80%)
- Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) (6%)
- High groundwater quality impacts (>10 times relevant standards) (6%)

Predicted surface water quality impacts were summarized and scored as follows:

- No information available (9%)
- Low surface water quality impacts (< relevant standards) (83%)
- Moderate surface water quality impacts (≥ and up to 10 times relevant standards) (7%)
- High surface water quality impacts (>10 times standards) (1%)

Predicted pit water quality impacts were summarized and scored as follows:

- No information available (16%)
- Low pit water quality impacts (concentrations less than relevant standards or water quality similar to surrounding groundwater) (17%)
- Moderate pit water quality impacts (≥ and up to 10 times relevant standards) (19%)
- High pit water quality impacts (>10 time relevant standards) (13%)
- No pit lake or water expected (underground mine or pit above the water table (35%)

In many cases, EISs identified mines or certain facilities at mines (e.g., heap leach pads or tailings impoundments) as "zero discharge" facilities. Many mines also had discharges to surface water that are regulated by either federal National Pollution Discharge Elimination System (NPDES) permits or similar permits issued by individual states under EPA authority.

Discharges were summarized and scored as follows:

- Zero Discharge Facilities (39%)
- Surface Water Discharge Permit (41%)
- Groundwater Discharge Permit (6%)

Each of the following sections describes the approach to categorizing the relevant NEPA information and summarizes and discusses the information collected from the 71 major mines for which we reviewed NEPA documentation. In Tables 5.5 through 5.22, the 25 mines subsequently chosen as case study mines are indicated by an asterisk (*). Identifying them in this section allows for a visual review of the variability in elements that may affect operational water quality.

5.2. GEOLOGY AND MINERALIZATION

Geology and mineralization information collected from the NEPA documents included rock type (e.g., general categories such as igneous, sedimentary, and metamorphic, and more detailed categories such as granite, dolomite, and greenstone), and information on mineralogy/ mineralization, alteration and ore associations. Plumlee and others have suggested that knowledge about mineralization type can help to predict the environmental behavior of ore deposits (e.g., Seal and Hammarstrom, 2003, for massive sulfide and gold deposits). Table 5.1 lists these mineralization types, examples, and associated rock types.

Table 5.1. Mineralization Types, Examples and Associated Rock Types

Mineralization Types	Examples	Associated Rock Types
Volcanogenic massive sulfide (VMS) deposits	Iron Mountain CA, Blackbird mine, ID	Volcanic: basaltic (Cyprus type), rhyolitic-andesitic (Kuroko-type); sedimentary rock such as turbidites and black shales (Besshi-type)
High sulfidation epithermal (quartz alunite epithermal) deposits	Summitville, CO, Red Mountain Pass, CO, Goldfield and Paradise Peak, NV, Mt. Macintosh, BC, Julcani, Peru	Silicic volcanic or intrusive rocks (e.g., quartz latite)
Porphyry Cu and Cu-Mo deposits	Globe, AZ, Mt.Washington, BC, Alamosa CO	Altered, intermediate-composition intrusive rocks
Cordilleran lode deposits	Butte, MT; Magma, AZ, Quiruvilca, Peru	Altered, intermediate-composition intrusive rocks
Climax-type porphyry Mo deposits	Climax, Henderson, Mt. Emmons, CO	Silica- and uranium-rich granitic or rhyolitic intrusions
Polymetallic vein deposits and adularia-sericite epithermal vein deposits	Central City, CO (polymetallic vein); Creede and Bonanza, CO; Comstock NV; Sado, Japan (adularia-sericite)	igneous intrusions
Hot-spring Au-Ag and Hg deposits	Leviathan, Sulphur Bank, and McLaughlin, CA; Round Mountain, NV	Epithermal and vein deposits; volcanic rocks
Skarn and polymetallic replacement deposits	Leadville, Gilman, and Rico, CO; New World, MT; Park City and Tintic, UT. Skarn deposits associated with porphyry-Mo, -Cu- Mo and -Cu deposits - Yerington, NV; Chino, NM	Outermost portions of intrusions or in sediments adjacent to the intrusions
Stratiform shale-hosted (SEDEX) deposits	Red Dog, Lik, and Drenchwater, Alaska; Sullivan, BC; Mt. Isa and Broken Hill, Australia	Black shale and chert-bearing host rocks
Mississippi-Valley-Type (MVT) deposits	Old Lead Belt, Viburnum Trend in Missouri, Tri-State (Missouri, Kansas, and Oklahoma), Northern Arkansas, Upper Mississippi (Wisconsin), and Central Tennessee districts	Dolostones, limestones, sandstones in sedimentary basins
Magmatic sulfide deposits	Sudbury Complex, Ontario; Duluth Complex, Minnesota; Stillwater Complex, MT; Bushveld Complex, South Africa	Layered mafic intrusions, ultramafic volcanic rocks or ultramafic accumulations
Banded-iron formation (BIF) deposits	Superior-type deposits -- Mesabi Iron Range, Minnesota; Marquette Iron Range, Michigan	Chemical sediments in which iron oxides, carbonates, silicates or sulfides are finely interlaminated or interbedded with chert or jasper.
Low-sulfide, gold-quartz vein deposits	Juneau Gold Belt and Fairbanks, Alaska; Mother Lode, CA	In quartz veins in medium-grade greenstone metamorphic rocks
Alkalic Au-Ag-Te vein deposits	Cripple Creek, CO; Boulder County, CO; Ortiz, NM; Zortman and Landusky, MT.	Diatremes or breccia pipes in alkalic igneous intrusive complexes

Source: Plumlee et al., 1999.

A synopsis of the geology and mineralization information for each mine with NEPA documentation was developed, focusing primarily on the geologic and mineralogical characteristics of the ore and the surrounding rock that would make mined materials more or less susceptible to acid drainage generation. The synopsis is only a generalized overview of all the rock types and mineralization present at the site, especially for rocks in the area of the ore deposit that will be mined. Based on the synopsis, a score was developed for each mine that focused on sulfide content and the presence of carbonates or other type of neutralizing rock or minerals. The score represents the overall reported mineralization, but rocks of one type could dominate environmental behavior at a given mine site. The major categories scored varied from low potential to create acid drainage to high potential to generate acidity and were:

- No/insufficient information available (0)
- Low sulfide content, carbonate present or hosted in carbonate (1)
- Low sulfide content, low carbonate content/carbonate not mentioned (2)
- Sulfides present, carbonate or moderate - high NP rock present (3)
- Sulfides present, no carbonates/carbonates not mentioned or associated with ore body (4)
- High sulfide content, carbonates low/not present (5)

A list of rock types and names and their associated relative neutralizing and acid-generating potential is taken from Plumlee (1999) and is contained in Table 5.2. In some cases, the geology of the deposit provided neutralizing ability, even if the rock type was other than carbonate. For example, the layered mafic intrusions of the Stillwater and East Boulder mines in Montana have inherent neutralizing ability even though they do not have carbonates. In addition, skarn deposits (which are not listed in Table 5.1), such as at the Battle Mountain Complex in Nevada and certain kinds of volcanic tuffs, such as at the Florida Canyon Mine in Nevada, can also provide moderate to high neutralizing ability.

Table 5.2. Rock Types and Names and Associated Relative Neutralizing and Acid-Generating Potential.

Rock Type	Subcategory	Rock Name	Relative Neutralizing and Acid-Generating Potential
Sedimentary	Chemical/ Biological	Limestone	High NP
		Dolomite	Mod – high NP
		Chert	Mod NP
	Detrital	Black Shale	Low - mod NP, low - mod AP
		Redbed shales	Mod NP
		Arkose	Low NP
		Calcareous sandstone	Low NP
		Quartzose sandstone	Low NP
Igneous	Intrusive	Carbonatite	High NP, Mod AP
		Ultramafic	Mod – high NP, mod AP
		Granite	Low NP
	Volcanic	Komatiite	Mod – high NP, some AP
		Basalt	Low – mod NP
		Andesite	Low – mod NP
		Poorly welded volcanic tuff	Mod – high NP
		Highly welded volcanic tuff	Low – mod NP
		Rhyolite flows	Low – mod NP
Metamorphic		Marble	High NP
		Gneiss	Low NP
		Quartzite	Very low NP
		Sulfidic schists	Low NP, high AP

Source: Plumlee, 1999.

Table 5.3 presents the mineralization/ore classifications for the 71 NEPA mines in the study. For mines with multiple EISs or EAs, the highest individual score was used.

Table 5.3. Mineral/Ore Associations

0		1		2		3		4		5	
No/insufficient information available		Low sulfide content, carbonate present or hosted in carbonate		Low sulfide content, low carbonate content/carbonate not mentioned		Sulfides present, carbonate or mod-high NP rock present		Sulfides present, no carbonates/carbonates not mentioned or associated with ore body.		High sulfide content, carbonates low/not present	
Fort Knox	AK	Cortez Pipeline	NV	Kensington Project	AK	AJ Project	AK	Bagdad	AZ	Montana Tunnels	MT
Pogo Project	AK	Dash	NV	Sanchez	AZ	Greens Creek	AK	Safford (Dos Pobres)	AZ	Golden Sunlight	MT
True North	AK	Griffon	NV	Yarnell	AZ	Red Dog	AK	Hayden Hill	CA		
Cyprus Tohono	AZ	Jerritt Canyon	NV	American Girl	CA	Carlotta	AZ	Beartrack	ID		
Morenci	AZ	Marigold	NV	Imperial	CA	Black Pine	ID	Grouse Creek	ID		
Ray	AZ	Olinghouse	NV			Stibnite	ID	Basin Creek	MT		
Castle Mountain	CA	Rochester	NV			Thompson Creek	ID	Beal Mountain	MT		
Jamestown	CA					Diamond Hill	MT	Black Pine	MT		
McLaughlin	CA					East Boulder	MT	Mineral Hill	MT		
Mesquite	CA					Rock Creek	MT	Montanore	MT		
Royal Mountain King	CA					Stillwater	MT	Troy	MT		
Stone Cabin	ID					Battle Mountain Phoenix	NV	Zortman Landusky	MT		
Austin Gold Venture	NV					Cortez	NV	Copper Flat	NM		
Bald Mountain	NV					Florida Canyon	NV	Tyrone Little Rock	NM		
Rain	NV					Gold Quarry	NV	Mule Canyon	NV		
Gilt Edge	SD					Goldstrike	NV	Lisbon Valley	UT		
						Leeville	NV	Flambeau	WI		
						Lone Tree	NV				
						Pete	NV				
						Robinson (Ruth)	NV				
						Round Mountain	NV				
						Ruby Hill	NV				
						Trenton Canyon	NV				
						Twin Creeks	NV				
	16		7		5		24		17		2

No/Insufficient Information Available

Almost one-quarter of the mines (23% or 16 mines) did not contain sufficient information to evaluate the mineralization or ore associations. Four of the mines, Fort Knox, True North, Austin Gold Venture, and Rain, had only EAs, while two of the mines, Morenci and Ray, had EISs conducted for land exchange purposes. The McLaughlin Mine is a shallow, low-sulfidation epithermal hot-spring deposit, but insufficient information was provided in the McLaughlin EIS to categorize it.

Low Sulfide Content, Carbonate Present or Hosted in Carbonate

Ten percent (7 mines) of the NEPA mines analyzed, all located in Nevada, had rocks with low sulfide content and carbonate present or hosted in carbonate. These mines would be expected to have a relatively low impact on the environment in terms of acid-generation potential.

Low Sulfide Content, Low Carbonate Content/Carbonate Not Mentioned

Five mines (7%) also had low sulfide content but had low carbonate content, or the presence of carbonates was not mentioned. The absence of carbonate would give these mines a somewhat higher potential to generate acid than those in the previous category. Jerritt Canyon is a sediment-hosted Carlin-type deposit, but the presence of sulfides was not mentioned in the Jerritt Canyon EISs, so it was placed in the low sulfide content, carbonate present or hosted in carbonate category.

Sulfides Present, Carbonate or Moderately High Neutralizing-Potential Rock Present

The highest number of mines (24 or 34%) had both sulfides and carbonate or moderately high neutralizing potential rock present. The sulfide content at these mines was not described as "low," so the potential for acid generation is higher than the first two categories. The majority of mines in this category are in Nevada, and four of these are sediment-hosted Carlin-Type deposits (Seal and Hammarstrom, 2003). Two of the Montana mines (East Boulder and Stillwater) were placed in this category because of the presence of moderately high neutralizing potential rock (ultramafic rocks), rather than because of their carbonate content. Mines in this category have higher sulfide content than those in the previous categories but also have neutralizing rock present. The potential acid drainage potential at mines in this category will depend on the relative amounts of sulfide and neutralizing material and the proximity to one another, the availability of these minerals to weathering, the rates at which they weather, and other factors, such as climatic conditions.

Sulfides Present, No Carbonates/Carbonates Not Mentioned or Associated with Ore Body

The next category, sulfides present with no carbonate, or carbonates not mentioned or associated with the ore body, contained 17 mines (24%), and most of these mines are in Montana. The mines in this group have a relatively high potential to generate acid because of the lack of neutralizing material and the presence of sulfides.

High Sulfide Content, Carbonates Low/Not Present

Mines in the last category (2 or 3%) have the highest potential to generate acid because of the high sulfide content and the lack of or low carbonate content. Of these two mines, Golden Sunlight has had extensive problems with acid drainage (see Section 6 and Appendix B).

5.3. CLIMATE

Climate information gathered from each EIS (and/or preceding EA) included general descriptions of climate type (i.e., arid, semi arid, coastal marine, northern, etc.) and information on the amount of precipitation and evaporation.

The climate descriptions in the NEPA documents varied substantially in detail and scope of coverage (e.g., most reported the amount of precipitation, but few reported the amount of evaporation). Descriptions in the documents included “arid” (14 mines), “semi-arid” (25 mines) and “long winter” (three mines). Other descriptions particular to individual mines included “coastal marine,” “continental highlands,” “high desert,” “modified continental,” “mountain,” “pacific maritime,” “southern,” and “temperate.”

Precipitation in terms of annual moisture was reported relatively consistently in every EIS analyzed. It was generally provided in terms of a range of average annual precipitation calculated as rainfall. As noted above, evaporation data were provided sporadically, with some EISs providing an annual figure or range and with others only saying “evaporation exceeds precipitation.”

In addition to recording the climate descriptions noted in the EISs, the Köppen system was used to characterize climate at each mine site. The Köppen system, developed by German climatologist and amateur botanist Wladimir Köppen in 1928, is a universally used system that allows for comprehensive and comprehensible climate classification. Köppen’s system has been widely modified, with Trewartha’s modified Köppen system being the most widely used version today.

The modified Köppen system uses letters to denote the six major climate regions and their sub-classifications. The sub-classifications are based on average monthly temperature and precipitation values. The regions and subclassifications are as follows:

Major Climate Regions

A for tropical humid climates
B for hot dry climates
C for mild mid-latitude climates
D for cold mid-latitude climates
E for polar climates
H for highland climates

Subtypes for Precipitation

s – dry season in summer, where: when 70% or more of annual precipitation falls in winter (for C climates)
w – dry season in winter, where: when 70% or more of annual precipitation falls in summer (for A, C, or D climates)
f – constantly moist, or: rainfall consistent throughout year (for A, C, or D climates)
m – monsoon rain, short dry season

Subtypes for Temperature

a - warmest month above or equal to 22°C
b – warmest month below 22°C (for C or D climates)
c – less than four months over 10°C (for C or D climates)
d – same as ‘c’ but coldest month below -37°C (for D climates)
h – hot and dry: all months above 0°C (for B climates)
k – cool and dry; at least one month below 0°C (for B climates)

Köppen classification maps were obtained for the states in which the 71 major NEPA mines analyzed were located, and mine locations were matched with climate classifications. Based on that information, the following climate classifications shown in Table 5.4 were derived for the 71 NEPA mines analyzed. It was possible to locate all 71 mines on the classification maps, so Köppen classifications are available for all the NEPA mines, even if details of the climatic conditions were not described in the EISs. Because the Köppen classification is characterized by its location on the maps and the same Köppen score was used for each EIS, concatenating scores from multiple EISs were not necessary.

Dry/Arid Low and Middle Latitude Deserts (B/C,w,h/k)

Regions classified as *B* with precipitation subtype w and temperature subtypes *h/k* are typified by the low latitude Sonoran desert of New Mexico and Arizona and the Mohave Desert of Arizona and California. Fourteen mines in those states fell into this classification, including all the mines reviewed in New Mexico, Arizona and southern California.

Dry/Semi-Arid Middle Latitude Climates (B/D,s,a)

Regions classified as *B/D* with precipitation subtype *s* and temperature subtype *a* are typified by the higher elevation mid-latitude valley and range deserts of Nevada and Utah. Twenty-four mines in those states fell into this classification, including all the mines reviewed in Nevada and Utah. Depending on elevation, the amount of precipitation and evaporation can vary significantly from site to site in this region.

Humid Subtropical (C,s,a)

Regions classified as *C* with precipitation subtype s and temperature subtype *a* are humid subtropical regions ("Mediterranean" climates) typified by the central and coastal areas of California. Three mines located in central California were reviewed in this classification.

Marine West Coast (C,f,b)

Regions classified as *C* with precipitation subtype *f* and temperature subtype *b* are marine west coast climates typified by mild but wet weather typified by the southern Alaska coast. Three of the six mines located in Alaska fell into this classification.

Boreal Forest (D,s,a)

Although some ecologists or foresters do not consider any forests in the United States to be "boreal," the Köppen classification recognizes this as a region in the United States. Regions classified as *D* with precipitation subtype *s* and temperature subtype *a* have moist, severe (cold) winter climates and cool summers typified by inland Boreal Forests. Nineteen mines in the states of Idaho and Montana and one in Northern California (20 total) fell into this classification (including all the mines reviewed in Idaho and Montana).

Continental (D,f,a)

Regions classified as *D* with precipitation subtype *f* and temperature subtype *a* have temperate climates with humid hot summers and year-round precipitation typified by the mid-western United States. Two mines located in South Dakota and Wisconsin fell into this classification.

Sub-Arctic (D,f,c)

Regions classified as *D* with precipitation subtype *f* and temperature subtype *c* have year-round precipitation and cool summers typified by the mainland of Alaska. Three mines located in Alaska were reviewed from this classification.

Table 5.4. Koppen Climate Classification

B/C,w,h/k)		B/D,s,a		C,s,a		C,f,b		D,s,a		D,f,a		D,f,c	
Dry/Arid Low and Middle Latitude Deserts		Dry/Semi-Arid Middle Latitude Climates		Humid Tropical		Marine West Coast		Boreal Forest		Continental		Sub Arctic	
Bagdad	AZ	Austin Gold Venture	NV	Royal Mountain King	CA	AJ Project	AK	East Boulder	MT	Gilt Edge	SD	Fort Knox	AK
Carlotta	AZ	Bald Mountain	NV	Jamestown	CA	Greens Creek	AK	Montana Tunnels	MT	Flambeau	WI	Pogo Project	AK
Cyprus Tohono	AZ	Battle Mountain Phoenix	NV	McLaughlin	CA	Kensington Project	AK	Beartrack	ID			True North	AK
Morenci	AZ	Cortez	NV			Red Dog	AK	Troy	MT				
Ray	AZ	Cortez Pipeline	NV					Montanore	MT				
Safford (Dos Pobres)	AZ	Dash	NV					Diamond Hill	MT				
Sanchez	AZ	Florida Canyon	NV					Basin Creek	MT				
Yarnell	AZ	Gold Quarry	NV					Hayden Hill	CA				
American Girl	CA	Goldstrike	NV					Black Pine	ID				
Castle Mountain	CA	Griffon	NV					Grouse Creek	ID				
Imperial	CA	Jerritt Canyon	NV					Stibnite	ID				
Mesquite	CA	Leeville	NV					Stone Cabin	ID				
Copper Flat	NM	Lone Tree	NV					Thompson Creek	ID				
Tyrone Little Rock	NM	Marigold	NV					Beal Mountain	MT				
		Mule Canyon	NV					Black Pine	MT				
		Olinghouse	NV					Golden Sunlight	MT				
		Pete	NV					Mineral Hill	MT				
		Rain	NV					Rock Creek	MT				
		Robinson (Ruth)	NV					Stillwater	MT				
		Rochester	NV					Zortman Landusky	MT				
		Round Mountain	NV										
		Ruby Hill	NV										
		Trenton Canyon	NV										
		Twin Creeks	NV										
		Lisbon Valley	UT										
	14		25		3		4		20		2		3

5.4. HYDROLOGY

Hydrology information gathered from each EIS (and/or preceding EA) included information on surface water proximity and groundwater depth. Descriptions varied widely from document to document, although most contained some information on both surface water proximity and groundwater depth.

5.4.1. SURFACE WATER PROXIMITY

Information on surface water proximity was entered into the database and classified according to one of four categories:

- No information provided (0)
- Intermittent/ephemeral streams on site - perennial streams >1 mile away (1)
- Intermittent/ephemeral streams on site - perennial streams <1 mile away (2)
- Perennial streams on site (3)

An intermittent stream is one that flows only during wet periods that are not tied to short-term storm events, for example, when it receives water from springs or melting snow. Ephemeral streams are those that flow only in response to precipitation and whose channel is always above the water table. Most desert drainages are ephemeral. In most cases, the streams were not identified as one or the other in the NEPA documents, so no distinction was made between these two types of non-perennial streams. Generally, mines with perennial streams on site are more susceptible to surface water quality impacts from mining than those with only intermittent or ephemeral streams on site.

For mines with multiple EISs or EAs, the highest individual score was used. If there are only intermittent or ephemeral streams on site but no distance to perennial surface water is noted, it was scored as a 2 (perennial streams <1 mile away). Direct discharges to surface water, including NPDES permits, are discussed in Section 5.1. Results for the surface water hydrology classifications are presented in Table 5.5.

No Information Provided

Five mines (7%) reviewed did not provide information on the proximity to surface water resources. In some cases, maps may have been included in the EIS, but insufficient information was provided on the maps (e.g., whether or not streams were perennial) to make a supportable classification. Of these five mines, one (Rain) had only an EA.

Intermittent/Ephemeral Streams on Site - Perennial Streams >1 Mile Away

Nineteen mines (27%) were classified as having intermittent and/or ephemeral streams on site and perennial streams greater than one mile away. This classification could also be summarized as “far from surface water.” The mines in this category were located in the southwestern states of New Mexico and Arizona and in California, Idaho, Nevada, and Utah.

Intermittent/Ephemeral Streams on Site - Perennial Streams <1 Mile Away

Sixteen mines (23%) were classified as having intermittent and/or ephemeral streams on site and perennial streams less than one mile away. This classification could also be summarized as “moderately far from surface water.” The mines in this category were located in Alaska, California, Montana, Nevada, and Wisconsin.

Perennial Streams on Site

The highest number of mines (31 or 44%) was classified as having perennial streams on site. This classification could also be summarized as "close to surface water." The mines in this category are located in Alaska, Arizona, California, Idaho, Montana, New Mexico, Nevada and South Dakota.

Table 5.5. Surface Water Proximity

0		1		2		3	
No information		Intermittent/ ephemeral streams on site - perennial streams >1 mile away		Intermittent/ ephemeral streams on site - perennial streams <1 mile away		Perennial streams on site	
Yarnell	AZ	Bagdad*	AZ	True North	AK	AJ Project	AK
Imperial	CA	Cyprus Tohono	AZ	McLaughlin*	CA	Fort Knox	AK
Royal Mountain King*	CA	Safford (Dos Pobres)	AZ	Golden Sunlight*	MT	Greens Creek *	AK
Diamond Hill	MT	Sanchez	AZ	Montana Tunnels	MT	Kensington Project	AK
Rain	NV	American Girl*	CA	Stillwater*	MT	Pogo Project	AK
		Castle Mountain*	CA	Austin Gold Venture	NV	Red Dog	AK
		Mesquite*	CA	Battle Mountain Phoenix	NV	Carlotta	AZ
		Black Pine	ID	Goldstrike	NV	Morenci	AZ
		Copper Flat	NM	Leeville	NV	Ray*	AZ
		Bald Mountain	NV	Marigold	NV	Hayden Hill	CA
		Cortez	NV	Pete	NV	Jamestown*	CA
		Cortez Pipeline	NV	Robinson (Ruth)	NV	Beartrack	ID
		Florida Canyon*	NV	Rochester*	NV	Grouse Creek*	ID
		Gold Quarry	NV	Round Mountain*	NV	Stibnite	ID
		Griffon	NV	Ruby Hill*	NV	Stone Cabin	ID
		Lone Tree*	NV	Flambeau*	WI	Thompson Creek*	ID
		Mule Canyon	NV			Basin Creek	MT
		Olinghouse	NV			Beal Mountain*	MT
		Lisbon Valley	UT			Black Pine*	MT
						East Boulder	MT
						Mineral Hill*	MT
						Montanore	MT
						Rock Creek	MT
						Troy	MT
						Zortman and Landusky*	MT
						Tyrone Little Rock	NM
						Dash	NV
						Jerritt Canyon*	NV
						Trenton Canyon	NV
						Twin Creeks*	NV
						Gilt Edge	SD
	5		19		16		31

Note: In Tables 5.5 through 5.22, the 25 mines chosen as case study mines are indicated by an asterisk (*).

5.4.2. DEPTH TO GROUNDWATER

Information on the depth to groundwater was entered into the database and classified according to one of four categories:

- No information provided (0)
- Depth to groundwater > 200 feet (1)
- Depth to groundwater < 200 but >50 feet (2)
- Depth to groundwater 0 to 50 feet and/or springs on site (3)

Table 5.6 contains the results of the scoring of the 71 NEPA mines for depth to groundwater. For mines with multiple EISs or EAs, the individual highest score was used. The shallowest depth to groundwater was used, even if the groundwater was described as being "perched," or if the groundwater was alluvial. If springs were noted on the site but there was no other information about the depth to groundwater, it was scored as a 3. Therefore, springs were considered an expression of groundwater rather than as surface water. In general, mines with shallower depths to groundwater are more susceptible to groundwater quality impacts than those with greater depths to groundwater.

No Information Provided

NEPA documentation from eight mines (11%) did not provide any information on the depth to groundwater. Two of these mines (True North, AK; Austin Gold Venture, NV) had only EAs.

Depth to Groundwater > 200 feet

Twelve mines (17%) were classified as having a depth to groundwater of greater than 200 feet. The mines in this category are considered to be far from groundwater resources and are located in Arizona, California, Montana and Nevada.

Depth to Groundwater < 200 but > than 50 feet

Nine mines (13%) were classified as having a depth to groundwater of less than 200 but greater than 50 feet. The mines with this classification are located in Arizona, California, Idaho, Montana and Nevada and Utah.

Depth to Groundwater Less Than 50 feet and/or Springs on Site

The largest number of mines (42 or 59%) was classified as having a depth to groundwater of less than 50 feet and/or having springs on site. The mines with this classification are located in Alaska, Arizona, California, Idaho, Montana, Nevada, South Dakota and Wisconsin.

Table 5.6. Depth to Groundwater.

0		1		2		3	
No information		Depth to groundwater >200 feet		Depth to groundwater <200 but >50 feet		Depth to groundwater 0 to 50 ft or springs on site with no other info	
AJ Project	AK	Ray*	AZ	Cyprus Tohono	AZ	Fort Knox	AK
True North	AK	Castle Mountain*	CA	Mesquite*	CA	Greens Creek*	AK
Carlotta	AZ	Montanore	MT	Black Pine	ID	Kensington Project	AK
Imperial	CA	Bald Mountain	NV	Mineral Hill*	MT	Pogo Project	AK
Royal Mountain King*	CA	Cortez Pipeline	NV	Marigold	NV	Red Dog	AK
Copper Flat	NM	Griffon	NV	Pete	NV	Bagdad*	AZ
Tyrone Little Rock	NM	Leeville	NV	Round Mountain*	NV	Morenci	AZ
Austin Gold Venture	NV	Mule Canyon	NV	Twin Creeks*	NV	Safford (Dos Pobres)	AZ
		Olinghouse	NV	Lisbon Valley	UT	Sanchez	AZ
		Rain	NV			Yarnell	AZ
		Ruby Hill*	NV			American Girl*	CA
		Trenton Canyon	NV			Hayden Hill	CA
						Jamestown*	CA
						McLaughlin*	CA
						Beartrack	ID
						Grouse Creek*	ID
						Stibnite	ID
						Stone Cabin	ID
						Thompson Creek*	ID
						Basin Creek	MT
						Beal Mountain*	MT
						Black Pine*	MT
						Diamond Hill	MT
						East Boulder	MT
						Golden Sunlight*	MT
						Montana Tunnels	MT
						Rock Creek	MT
						Stillwater*	MT
						Troy	MT
						Zortman and Landusky*	MT
						Battle Mountain Phoenix	NV
						Cortez	NV
						Dash	NV
						Florida Canyon*	NV
						Gold Quarry	NV
						Goldstrike	NV
						Jerritt Canyon*	NV
						Lone Tree*	NV
						Robinson (Ruth)	NV
						Rochester*	NV
						Gilt Edge	SD
						Flambeau*	WI
	8		12		9		42

5.5. GEOCHEMICAL CHARACTERIZATION AND MODELING

5.5.1. TESTING METHODS

Information was gathered from each EIS (and/or preceding EA) on the types of laboratory and field geochemical testing methods used to characterize the potential of the project to generate acid and leach contaminants of concern. The general methods listed included:

- whole rock analysis
- mineralogy
- paste pH
- sulfur analysis
- static testing
- short-term leach testing
- kinetic testing
- other additional tests

A number of the methods have sub-categories; for example, types of short-term leach testing methods include the Nevada Meteoric Water Mobility Procedure (MWMP), U.S. EPA's Synthetic Precipitation Leaching Procedure (SPLP), and the California Waste Extraction Test (CA WET). A review of the different types of geochemical characterization methods is contained in the companion report to this document (Maest et al., 2005). It is possible that additional geochemical characterization methods were performed but not mentioned in the NEPA documents. For example, although sulfur analysis was not specifically mentioned, it may have been conducted as part of the acid-base accounting evaluation. Similarly, mineralogical analysis may have been conducted as part of evaluating the ore body, but the results may not have been presented in the NEPA documents.

The scoring for this category focused on the main types of geochemical characterization tests used: static, short-term leach, and kinetic testing, and were scored at follows:

- No information (0)
- Static testing only (1)
- Short-term leach testing only (2)
- Kinetic testing only (3)
- Static and short-term leach testing (4)
- Static and kinetic testing (5)
- Short-term leach and kinetic testing (6)
- Static, short-term leach, and kinetic testing (7)

Tests identified as "weather" or "weathering" were assumed to be kinetic tests, and column or barrel testing for heap detoxification was also considered to be kinetic testing. For mines with multiple EISs, the EIS with the most types of testing (highest score) was recorded. Table 5.7 lists the types and combinations of types of geochemical characterization tests that were mentioned for the 71 NEPA mines with EISs and EAs that were reviewed.

Table 5.7. Geochemical Characterization

0		1		2		3		4		5		6		7	
No lab/field predictive testing conducted/type unknown		Static testing only		Short-term leach testing only		Kinetic testing only		Static and short-term leach testing conducted		Static and kinetic testing conducted		Short-term leach and kinetic testing		Static, short-term leach, and kinetic testing conducted	
AJ Project	AK	True North	AK	Carlotta	AZ	Basin Creek	MT	Safford (Dos Pobres)	AZ	Fort Knox	AK	Mineral Hill*	MT	Greens Creek*	AK
Red Dog	AK	Bagdad*	AZ	Imperial*	CA			Sanchez	AZ	Pogo Project	AK			Kensington Project	AK
Morenci	AZ	Cyprus Tohono	AZ	Jamestown*	CA			American Girl*	CA	Mesquite*	CA			Yarnell	AZ
Ray*	AZ	Royal Mountain King*	CA	Austin Gold Venture	NV			Castle Mountain*	CA	Stibnite	ID			Hayden Hill	CA
Black Pine	MT	Montana Tunnels	MT					McLaughlin*	CA	Stone Cabin	ID			Beartrack	ID
East Boulder	MT	Montanore	MT					Black Pine	ID	Diamond Hill	MT			Thompson Creek*	ID
Troy	MT	Tyrone Little Rock	NM					Grouse Creek*	ID	Rock Creek	MT			Beal Mountain*	MT
Rain	NV	Cortez	NV					Bald Mountain	NV	Copper Flat	NM			Golden Sunlight*	MT
		Mule Canyon	NV					Griffon	NV	Dash	NV			Stillwater*	MT
		Pete	NV					Leeville	NV	Gold Quarry	NV			Zortman Landusky*	MT
								Trenton Canyon	NV	Goldstrike	NV			Battle Mountain Phoenix	NV
								Lisbon Valley	UT					Cortez Pipeline	NV
														Florida Canyon*	NV
														Jerritt Canyon*	NV
														Lone Tree*	NV
														Marigold	NV
														Mule Canyon	NV
														Olinghouse	NV
														Robinson (Ruth)	NV
														Rochester*	NV
														Round Mountain*	NV
														Ruby Hill*	NV
														Twin Creeks*	NV
														Gilt Edge	SD
														Flambeau*	WI
	8		9		4		1		12		11		1		25

No Information Provided

Eleven percent of the mines (8) either did not perform geochemical characterization, did not mention that they performed testing, or did not mention the type of testing performed. Of these, two had land-exchange EISs (Morenci and Ray, AZ), and one had an EA (Rain, NV).

Static Acid-Base Accounting (ABA) Testing Only

Nine mines (13%) performed static testing only. Three of these mines (True North, AK; Royal Mountain King, CA; Pete, NV) had EAs. (The 1987 document for Royal Mountain King was an EIR/EA). The remaining six mines had EISs, and two of these were in Arizona, two in Montana, one in New Mexico, and one in Nevada. Eight of the mines mentioned acid-base accounting testing with no mention of the type of ABA testing performed, and one, (Pete, NV), owned by Newmont, used net carbonate value testing (NCV), a method developed by Newmont.

Short-term Leach Testing Only

Four mines (6%) conducted only short-term leach testing. One (Austin Gold Venture, NV), was permitted with a 1986 EA; no mention of the type of short-term leach testing was made for this mine. Of the other three mines, two were in California and one was in Arizona. The Carlotta Mine in Arizona used the meteoric water mobility procedure (MWMP) test devised by the State of Nevada; the Jamestown Mine in California used the California waste extraction test (WET); and the Imperial Mine in southern California used three EPA short-term leach methods, the Extraction Procedure (EP) Toxicity test (Method 1310), the Synthetic Precipitation Leaching Procedure (SPLP – Method 1312), and the Multiple Extraction Procedure (MEP – Method 1320). Information on the details of these methods is contained in Maest et al. (2005).

Kinetic Testing Only

One mine (1%)(Basin Creek Mine, MT) conducted only kinetic testing. The kinetic method used was column testing of the spent ore for heap cyanide detoxification (rinsing with the heap with hydrogen peroxide to break down cyanide). This method is not traditionally considered to be kinetic testing (as humidity cell testing is), but it does test behavior of mined material over a longer time period and is therefore categorized as kinetic testing for the purposes of this study.

Static and Short-term Leach Testing

Twelve mines (17%) performed both static testing and short-term leach testing. All of these mines had EISs rather than EAs. Ten of the mines identified the static testing only as acid-base accounting testing. The McLaughlin Mine in California employed a static acid-base accounting test that used hydrogen peroxide, similar to the net acid generating (NAG) test used more commonly in Australia and Southeast Asia. The Leeville Mine in Nevada, owned by Newmont, used the net carbonate value (NCV) acid-base accounting test.

Five of the mines that used both static and short-term leach testing used the synthetic precipitation leaching procedure (SPLP, EPA Method 1312), two of the mines (American Girl and McLaughlin) used the California waste extraction procedure (CA WET), four of the mines (all in Nevada) used the meteoric water mobility procedure (MWMP), one used the extraction procedure (EP) toxicity test, and one had no information on the type of short-term leach testing employed. See Maest et al. (2005) for a review of the testing procedures and their advantages and disadvantages. Two mines (American Girl and McLaughlin) performed two types of short-term leach testing, CA WET and SPLP and deionized water extraction and CA WET, respectively.

Static and Kinetic Testing

Eleven mines (16%) performed both static testing and kinetic testing. Only one of these mines, (Fort Knox, AK) had an EA; all others had EISs. For the static testing, nine of the mines mentioned only acid-base accounting testing, one did not mention the type of static testing used, and one (Gold Quarry/Maggie Creek, NV), owned by Newmont, used the NCV method.

For the kinetic testing, five mines used humidity cell tests (HCT), five used column tests, one used "weathering tests," and three did not provide any information on the type of kinetic testing used (two mines used two types of kinetic testing).

Short-term Leach and Kinetic Testing

One mine (1%), (Mineral Hill Mine, MT) conducted both short-term leach and kinetic testing. Batch extraction and column tests were used at this mine.

Static, Short-term Leach, and Kinetic Testing

Twenty-five mines (35%) conducted static, short-term leach and kinetic testing. All these mines had EISs rather than EAs. Thirteen of the mines were in Nevada, four in Montana, two in Alaska, two in Idaho, and one each in California, South Dakota and Wisconsin. For static testing, the Greens Creek Mine in Alaska used the BC Research (modified) test; the Beal Mountain Mine in Montana mentioned using the modified Sobek method; and the Golden Sunlight Mine in Montana and the Marigold and Robinson (Ruth) mines in Nevada mentioned using the NAG test. None of the other mines specified which type of ABA testing was used.

For the short-term leach testing, ten of the mines (all in Nevada) used the MWMP test; seven of the mines used the SPLP test; two used the TCLP test; two used the EP Toxicity test, one used the soluble/total threshold limit test; one used the shake flask test; one used sequential saturated rolling extractions; and two had no information on the type of short-term leach test used. Some of the mines used multiple types of short-term leach methods.

For the kinetic testing, 18 mines used humidity cell tests, six used column tests, and four provided no information on the type of kinetic testing used. Some mines used multiple types of kinetic testing, all including HCT and "weathering," field extractions or column tests.

Static Testing – Overall Summary

Eighty percent of the mines (56) reported conducting some kind of static testing. A wide variety of static test methods were identified. Forty-eight of the mines (69%) did not specify the type of static testing or listed acid-base accounting (ABA) without listing the type of ABA method used (e.g., Sobek, modified Sobek – see Maest, et al., 2005). One mine (Beal Mountain, MT) mentioned using the modified Sobek method, and one mine (Greens Creek, AK) mentioned using the modified BC Research technique. Four of the mines that conducted static testing mentioned using the net acid generating (NAG) technique or a technique similar to the NAG method. Three of the mines (Gold Quarry, Leeville, Pete, NV), all owned by Newmont, mentioned using the net carbonate value (NCV) approach.

Short-term Leach Tests – Overall Summary

Short-term leach test methods were identified at 41 (59%) of the 71 mines. Five of the mines (7%) did not specify which type of short-term leaching method they used. Two of the mines (Jamestown and McLaughlin, CA) used the California waste extraction test; four of the mines used the older EP Toxicity test (EPA Method 1310); two of the mines used the Toxicity Characteristic Leaching Procedure (TCLP, EPA Method 1311), and 12 of the mines (17%) used the Synthetic Precipitation Leaching Procedure (SPLP, EPA Method 1312). Fifteen of the mines (21%) (14 in Nevada; Carlotta, AZ) used the Nevada MWMP.

Kinetic Testing – Overall Summary

Kinetic testing was identified at 38 (54%) of the 71 NEPA mines. Of the mines that reported conducting kinetic testing, the most common method was humidity cell testing (23 or 33%). Eight of the mines (11%) did not specify the type of kinetic testing conducted, and thirteen (19%) of the mines reported conducting column tests. Descriptions of the kinetic tests varied and included 10- week, 15- week and 21- to -39- week humidity cell tests;, column leach tests;, laboratory weathering testes, and long-term field leaching extract tests.

Slightly fewer than half (31) of the mines (44%) therefore, did not conduct any long-term testing of mined materials, and 38 mines (54%) did conduct kinetic testing to estimate the long-term environmental behavior of mined materials. A number of the mines that conducted kinetic testing only reported pH and/or pH and sulfate measurements for their kinetic testing results. Therefore, very few mines reported on the long-term potential for contaminant leaching, other than for acidity and sulfate generation.

Other Types of Geochemical Characterization

Sulfur Analysis

Of the mines that did report conducting sulfur analyses (16 or 23%), two did not mention the type of sulfur analysis performed, five (31%) conducted only total sulfur analysis, six (38%) reported total and sulfide or pyritic sulfur analysis, and three (19%) conducted the most thorough possible analysis: total sulfur and sulfur fractions (potentially including total, sulfate, organic, pyritic and sulfide sulfur forms).

Additional Tests

Additional types of geochemical characterization tests that were identified in the EISs included barrel or other types of tests to simulate heap rinsing, trace element analysis, petrographic analysis, infiltration tests conducted on waste rock piles, and studies on mixing acid leachate with groundwater.

5.5.2. CONSTITUENTS OF CONCERN IDENTIFIED

Constituents of concern (COCs) were identified in the EISs directly (specifically called constituents of concern or contaminants of concern) or indirectly (e.g., as constituents that were present at elevated levels in leachate or as analytes in required monitoring programs). Table 5.8 lists the identified constituents of concern for the 71 mines. The general categories of constituents of concern and specific examples cited in the EISs were:

- metals (aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, silver, thallium, tin, zinc)
- radionuclides (radium, uranium)
- anions and nitrogen compounds (sulfate, nitrate/nitrite/ammonia (from blasting), fluoride)
- cyanide (cyanide and compounds)
- metalloids, oxyanions (antimony, arsenic, molybdenum, selenium, tungsten, vanadium)
- conventional pollutants (total dissolved solids, total suspended solids, pH, organics, nutrients (e.g., phosphate or nitrogen compounds not resulting from blasting), sediment, salts (e.g., chloride, sodium), turbidity, oil and grease)

Because a given mine often had more than one constituent of concern (e.g., metals and anions and cyanide), the percentage of mines with COCs in all the above categories sums to more than 100%. For mines with multiple EISs or EAs, if a COC was mentioned in any of the EISs, it was included as a COC for the mine as a whole.

Table 5.8 shows that 11 of the 71 mines (16%) had no information or insufficient information on constituents of concern. The largest number of mines, 51 (74%) identified metals as COCs, while nearly equal numbers of mines identified anions and nitrogen compounds, metalloids and oxyanions, and conventional pollutants as COCs (ranging from 49% to 58%). Only 16 of the mines (23%) identified cyanide as a constituent of concern; this number does not include all heap leach and vat leach precious metals operations – only the ones that specifically identified cyanide as a constituent of concern. Only one mine (Lisbon Valley Copper, UT) identified radionuclides (uranium and radium) as a constituent of concern.

Table 5.8. Identified Constituents of Concern

Score	Category	Number in category	Percent
0	None/insufficient information	11	15.9%
1	Metals	51	73.9%
2	Radionuclides	1	1.4%
3	Anions and nitrogen compounds	40	58.0%
4	Cyanide	16	23.2%
5	Metalloids, oxyanions	38	55.1%
6	Conventional pollutants	34	49.3%

The most commonly identified metals of concern were cadmium (24 mines), copper (29 mines), lead (20 mines), iron and manganese (22 mines each) and zinc (28 mines). Mercury was identified as a COC in sixteen mines. The most commonly identified metalloid of concern was arsenic (28 mines). Selenium (15 mines) and antimony (11 mines) were also mentioned as metalloid COCs at a number of mines. The most commonly identified anions of concern were sulfate (26 mines) and nitrate (16 mines). The most commonly mentioned conventional pollutants were total dissolved solids (19 mines) and pH (15 mines). Four mines mentioned elevated or high pH as a potential concern (Bear Track, ID; Copper Flat, NM; Marigold, NV; Lisbon Valley Copper, UT).

5.5.3. PREDICTIVE MODELS USED

The EISs and EAs from the 71 NEPA mines were reviewed to determine whether water quantity or water quality predictive models were used, and if so, what types of predictive model or models were used. The information on general types of predictive models used was classified and scored according to one of four categories:

- No predictive models used (0)
- Only water quantity predictive models used (1)
- Only water quality predictive models used (2)
- Both water quantity and water quality predictive models used (3).

For mines with multiple EISs, if a predictive model was used in any of the EISs, it was included for the mine as a whole. Table 5.9 lists the general types of predictive models used at the 71 NEPA mines.

No Predictive Models Used

No predictive models were used at 31 (44%) of the 71 NEPA mines. Eight of these mines were in Montana, seven in Nevada, five in Arizona, four in California, four in Alaska, one in Idaho, and one in New Mexico. Of these, seven had EAs, and the remainder had EISs.

Only Water Quantity Predictive Models Used

Of the mines that did report using predictive models, water quantity only (not combined with water quality models) predictive models were identified as being used at 18 (25%) of the mines. The water quantity models included surface transport models (SEDCAD), groundwater modeling (FLOWPATH) and infiltration modeling (HELP). The

Table 5.9. Predictive Models Used

0		1		2		3	
No predictive models used		Water quantity predictive model only		Water quality predictive model only		Water quality and quantity predictive models used	
AJ Project	AK	Sanchez	AZ	Flambeau*	WI	Greens Creek *	AK
Fort Knox	AK	Yarnell	AZ			Pogo Project	AK
Kensington Project	AK	American Girl*	CA			Safford (Dos Pobres)	AZ
Red Dog	AK	Hayden Hill	CA			Mesquite*	CA
True North	AK	Imperial	CA			Thompson Creek*	ID
Bagdad*	AZ	Beartrack	ID			Golden Sunlight*	MT
Carlotta	AZ	Grouse Creek*	ID			Montanore	MT
Cyprus Tohono	AZ	Stibnite	ID			Tyrone Little Rock	NM
Morenci	AZ	Stone Cabin	ID			Battle Mountain Phoenix	NV
Ray*	AZ	Mineral Hill*	MT			Cortez Pipeline	NV
Castle Mountain*	CA	Stillwater*	MT			Gold Quarry	NV
Jamestown*	CA	Zortman and Landusky*	MT			Goldstrike	NV
McLaughlin*	CA	Bald Mountain	NV			Lone Tree*	NV
Royal Mountain King*	CA	Dash	NV			Marigold	NV
Black Pine	ID	Florida Canyon*	NV			Mule Canyon	NV
Basin Creek	MT	Griffon	NV			Olinghouse	NV
Beal Mountain*	MT	Leeville	NV			Robinson (Ruth)	NV
Black Pine*	MT	Lisbon Valley	UT			Round Mountain*	NV
Diamond Hill	MT					Ruby Hill*	NV
East Boulder	MT					Twin Creeks*	NV
Montana Tunnels	MT					Gilt Edge	SD
Rock Creek	MT						
Troy	MT						
Copper Flat	NM						
Austin Gold Venture	NV						
Cortez	NV						
Jerritt Canyon*	NV						
Pete	NV						
Rain	NV						
Rochester*	NV						
Trenton Canyon	NV						
	31		18		1		21

types of water quantity codes used included: the near-surface-process hydrologic process codes HEC-1 and HELP (used at four of the mines) for infiltration, evaporation, and runoff; the codes SEDCAD (used at three of the mines), MUSLE, RUSTLE, and R1/R4SED for predicting sediment movement or effects of sedimentation on streams; a code for developing storm hydrographs (WASHMO); groundwater flow models (MODFLOW - reported being used at two of the sites); vadose zone models (HYDRUS) and drawdown models (at two mines). One mine, (Lone Tree, NV) used the propriety code MINEDW to predict 3-dimensional groundwater flow. See Maest et al. (2005) for a review of these models.

Only Water Quality Predictive Models Used

One mine (Flambeau Mine, WI) used a geochemical model only (not in combination with a water quantity model) to predict the concentration of contaminants in leachate in the backfilled pit.

Both Water Quantity and Water Quality Predictive Models Used

Twenty-one (30%) of the mines used a combination of water quantity and water quality models to predict water quality impacts after mining began. Of these, some mines used a water quantity code in combination with the geochemical codes PHREEQE (3 mines), WATEQ (1 mine), or MINTEQ (five mines), or PYROX or other type of pyrite oxidation code (3 mines). One mine used the code LEACHM to simulate water balance and contaminant transport. Three mines in Nevada used the CE-QUAL-W2 to simulate pit water flow and limited water quality characteristics and one mine used CE-Qual-R1. Four mines used unspecified mass balance or mass loading modeling (and the Tyrone/Little Rock Mine in New Mexico specifically mentioned using FLOWPATH), and five mines used proprietary models to predict pit water concentrations or groundwater concentrations downgradient of a waste rock facility.

5.6. WATER QUALITY IMPACT POTENTIAL

In this report we distinguish between potential and predicted water quality impacts. A potential water quality impact is one that could occur if mitigation are not in place, and predicted water quality impacts are those that threaten water quality even after mitigation are in place. Potential water quality impacts are related to the inherent characteristics of the mined materials. For example, tailings could have a potential to impact downgradient water quality if they have elevated acid drainage potential or contaminant leaching potential. However, if the tailings are in a properly lined facility with a backup capture system or are backfilled as a paste in underground workings or a tailings impoundment, their predicted water quality impacts could be low.

The elements of water quality impact potential include acid drainage potential, contaminant leaching potential, and potential groundwater, surface water and pit water impacts.

5.6.1. ACID DRAINAGE POTENTIAL

Information on acid drainage potential was based on static testing results, sulfur or pyrite contents or simply on statements in the EIS or EA that described the acid drainage potential as “low,” “moderate,” or “high” or that the material does or does not have the potential to produce acid. Identification of existing acid drainage was reported in some cases, but more importance was placed on the potential for acid drainage for the proposed project that was the subject of the EIS or EA.

The information on acid drainage potential contained in the EISs was summarized and scored as follows:

- No information available (0)
- Low acid drainage potential (1)
- Moderate acid drainage potential (2)
- High acid drainage potential (3)

Table 5.10 contains the names of the mines in the four categories for acid drainage potential. The recorded potential for acid drainage is for unit/material with the greatest potential to produce acid. If the EIS statement was somewhat negative (e.g., the potential for acid drainage exists), the entry was scored as a 2 (moderate potential to generate acid).

For mines with multiple EISs, the EIS with the highest potential to generate acid was used as the score for the mine. Mines with low acid drainage potential also include mines with material that has the potential to generate high-pH waters.

Table 5.10. Acid Drainage Potential

0		1		2		3	
No information available		Low		Moderate		High	
AJ Project	AK	Fort Knox	AK	Greens Creek*	AK	Red Dog	AK
Morenci	AZ	Kensington Project	AK	Carlotta	AZ	Black Pine*	MT
Ray*	AZ	Pogo Project	AK	Hayden Hill	CA	Golden Sunlight*	MT
Austin Gold Venture	NV	True North	AK	Grouse Creek*	ID	Zortman and Landusky*	MT
Rain	NV	Bagdad*	AZ	Stone Cabin	ID	Battle Mountain Phoenix	NV
Flambeau*	WI	Cyprus Tohono	AZ	Thompson Creek*	ID		
		Safford (Dos Pobres)	AZ	Beal Mountain*	MT		
		Sanchez	AZ	Diamond Hill	MT		
		Yarnell	AZ	Montana Tunnels	MT		
		American Girl*	CA	Montanore	MT		
		Castle Mountain*	CA	Gold Quarry	NV		
		Imperial	CA	Goldstrike	NV		
		Jamestown*	CA	Jerritt Canyon*	NV		
		McLaughlin*	CA	Leeville	NV		
		Mesquite*	CA	Lone Tree*	NV		
		Royal Mountain King*	CA	Mule Canyon	NV		
		Beartrack	ID	Pete	NV		
		Black Pine	ID	Robinson (Ruth)	NV		
		Stibnite	ID	Rochester*	NV		
		Basin Creek	MT	Twin Creeks*	NV		
		East Boulder	MT				
		Mineral Hill*	MT				
		Rock Creek	MT				
		Stillwater*	MT				
		Troy	MT				
		Copper Flat	NM				
		Tyrone Little Rock	NM				
		Bald Mountain	NV				
		Cortez	NV				
		Cortez Pipeline	NV				
		Dash	NV				
		Florida Canyon*	NV				
		Griffon	NV				
		Marigold	NV				
		Olinghouse	NV				
		Round Mountain*	NV				
		Ruby Hill*	NV				
		Trenton Canyon	NV				
		Gilt Edge	SD				
		Lisbon Valley	UT				
	6		40		20		5

Some of the conditions thought to limit the potential for acid drainage (as stated in the EISs) were: a limited amount of water or oxygen; removal of sulfide ore from the open pit; silica buffering, encapsulating of sulfides in silica; and lack of acid drainage from past mining activity at the same site. Some EISs predicted low to moderate acid drainage potential based on the results of kinetic testing even though static testing results suggested that acid drainage could form. Finally, several mines acknowledged that acid drainage could not be accurately predicted.

No Information Available

Six mines (8%) had EISs or EAs that made no mention of acid drainage potential. Of these, two were land-exchange EISs (Morenci, Ray, AZ), and two were evaluated with EAs rather than EISs (Austin Gold Venture, Rain, NV). The EIS for the AJ Project in Alaska had no direct mention of acid drainage potential. The EIS for the Flambeau Mine in Wisconsin mentioned that tests indicated that waste rock with sulfur content of 2% or less would not be expected to produce acid, but there was no indication of the amount of high (or low) sulfur material present.

Low Acid Drainage Potential

The acid drainage potential for the majority of mines (40 or 56%) was described as being low or nonexistent. Eleven of these mines were in Nevada; seven were in California; six were in Montana; five were in Arizona; four were in Alaska; three were in Idaho; two were in New Mexico; one was in South Dakota (Gilt Edge); and one was in Utah (Lisbon Valley Copper).

EISs for four of these mines provided no information on or did not perform static or kinetic testing of mined materials. The Imperial Mine, California, EIR stated that the waste rock and leached ore had high acid neutralization potential, but no information was provided in the EIR on static or kinetic test methods or results. Similarly, the Jamestown Mine, California, EIR stated that chemical analysis of the overburden material indicated that it is non-hazardous, non-toxic, and non-acid generating, but no information was provided in the EIR on the type or results of the chemical tests. The East Boulder Mine in Montana performed no static or kinetic testing, but appears to base the low acid drainage potential on the low sulfur content. The EIS for the Troy Mine in Montana also had no information on static or kinetic tests in the EIS. This EIS is over 20 years old, and it stated that the mineralogy of the host rocks and the type of minerals being mined apparently do not produce acid mine water.

The remainder of the mines did perform some kind of static or kinetic testing, but in a number of cases, the statements about low acid drainage potential did not appear to be based on test results. For example, unsupported statements such as "not expected to generate acid" were found in EISs for True North in Alaska, Stillwater Mine in Montana (1992 EIS), and Basin Creek in Montana, and the low acid generation potential was based on the low sulfur content in the East Boulder, Montana and Fort Knox, Alaska EISs. Some mines appeared to base the prediction of low acid drainage potential at least in part on existing conditions (i.e. no observed acid drainage related to past mining activities) at the mine (e.g., Bagdad, AZ; Troy, MT; Copper Flat, NM; Kensington, AK (1992 EIS); Rock Creek, MT (1998 EIS)).

Some mines predicted that there would be moderate or high acid drainage potential based on static tests but downgraded the potential to low based on kinetic tests. For example, at the Florida Canyon Mine in Nevada, unoxidized sulfide rock was considered to have the potential to generate acid based on static testing. However, results from "reanalyzed" samples and kinetic testing indicted that the rock was not acid generating because no samples with ANP:AGP <1 had kinetic test pH values <5.75 (note that pH standards for natural waters are always >6).

The Copper Flat, New Mexico, EIS stated that ABA tests indicated that the waste rock may have the potential to generate acid, but column kinetic tests of the unoxidized rock showed little oxidation after 20 weeks. Similarly, the 2001 Marigold, Nevada, EIS stated that not all waste rock was non-acid-generating, but column kinetic testing did not generate acid in 20 weeks. In the 1997 EIS for the Kensington, Alaska, mine, static testing results on ore were in an area of uncertainty for acid generation potential (NP:AP = 1-3), but results from kinetic testing produced no acid within 20 weeks of testing. As noted in Maest et al. (2005), a number of workers consider that 20 weeks is too short of a time period for kinetic testing.

EISs for two mines in this category stated that low amounts of water would limit acid drainage (Mineral Hill, Montana (1986 EIS) and Cortez Pipeline, Nevada (2000 EIS). The 2001 Rock Creek EIS also noted that the lack of exposure of sulfides to oxygen in the underground mine would limit acid drainage.

Three mines in this category acknowledged that acid drainage could not be accurately predicted. The 1978 EIS for the Troy Mine in Montana stated that no predictive tests were available to determine whether or not the mined material would generate acid. The Lisbon Valley, Utah, Mine EIS stated that impacts to groundwater or the pit could not be predicted based on the level of testing to date. The 1995 EIS for the Rock Creek Mine in Montana EIS stated that the long-term potential for acid drainage was unknown, as static tests would not predict this with certainty, and that kinetic tests would be useful. Kinetic tests were performed on material from the nearby Troy Mine, and based on these results, subsequent EISs also predicted that acid generation potential would be low. Although uncertainty about acid generation potential is acknowledged in the 1998 Rock Creek EIS, the potential for acid drainage from the tailings was predicted to be low.

Moderate Acid Drainage Potential

The EISs for 20 mines (28%) indicated moderate acid drainage potential. The mines in this category included two in Alaska (Greens Creek and Red Dog), one in Arizona (Carlotta), one in California (Hayden Hill), three in Idaho, four in Montana, and 10 in Nevada. The Lone Tree, Nevada mine EIS identified the moderate acid drainage potential based on to static testing results but also noted that kinetic tests did not produce acid, that the sulfides are encapsulated in silica and that silica buffering is important. The Mule Canyon, NV mine EIS acknowledged the potential generation of acid if the excavated mine materials were to come in contact with water.

Two of the mines in this category (Carlotta, AZ and Thompson Creek, ID) acknowledged some potential to generate acid but also noted that removal of sulfide ore from the open pit would leave little source of acid generation in the open pits. The 1984 EIS for the Grouse Creek, Idaho, Mine stated that even though an historic mine on the property had acid drainage from a portal, conditions would be different for the proposed mine. The EIS for the Montanore Mine in Montana stated that post-mining water quality could be acidic, but that acid drainage could not be accurately predicted. The EIS for the Diamond Hill Mine in Montana stated, as did some of those mines in the low acid drainage potential category, that the dry climate, low permeability transmissivity of the country rock, the total lack of discharge from an existing adit, and the lack of seeps or springs in the area, would limit the amount of acid drainage forming at the site. Some samples from the Robinson (Ruth) Mine in Nevada had large negative net carbonate values (NCV – indicative of acid drainage potential), but the EIS stated that 20-week kinetic results had near-neutral pH values (6-7), and that the high percentage of carbonate rocks in the pit area after mining would result in neutral drainage.

High Acid Drainage Potential

Only five mines were identified as having high acid drainage potential. It is notable that none of the original EISs (Golden Sunlight and Zortman and Landusky, MT) or EAs (Black Pine, MT; Battle Mountain Phoenix, NV) for these mines indicated high acid drainage potential, and it was only recognized in all cases by EISs or EAs that were written following actual evidence of acid drainage occurring.

5.6.2. CONTAMINANT LEACHING POTENTIAL

Information on contaminant leaching potential was typically based on constituents identified in short-term leach test results, although some limited information was also available from longer-term kinetics testing results. If quantitative information on contaminant leaching potential was available (i.e., concentrations in short-term or kinetic test leachate), these results were compared to water quality standards (drinking water or other standards or criteria, as identified in the EISs). In other cases, the contaminant leaching potential was identified qualitatively. The contaminants identified were most often metals/metalloids, although other contaminants such as cyanide, sulfate, and/or nitrates were also listed.

The information on contaminant leaching potential was summarized and scored according to the following four categories:

- No information available (0)
- Low contaminant leaching potential (leachate does not exceed water quality standards) (1)
- Moderate potential for elevated contaminant concentrations (leachate exceeds water quality standards by 1-10 times) (2)
- High potential for elevated contaminant concentrations (leachate exceeds water quality standards by over 10 times) (3)

The categories and factors chosen to score and describe contaminant leaching potential are not absolute in terms of potential environmental impact because different mines used different types of leaching procedures with different solid:liquid ratios (see Maest, et al., 2005) and different approaches to qualitatively describing the contaminant leaching potential. In addition, the potential for contaminant leaching is predicted without considering mitigation measures. The Environmental Protection Agency Potential uses TCLP leachate standards for hazardous waste that are based on 100 times the drinking water standards. However, we are using the four categories listed above as a conservative approach (environmentally protective) to gain a rough understanding of the potential for contaminant leaching from mining waste.

In the scoring, contaminant leaching potential was categorized according to the unit or material with the greatest potential to produce contaminants. For the entries with qualitative descriptions of the potential for contaminant leaching, if the EIS statement was somewhat negative (e.g., the potential for contaminant leaching exists), the entry was scored as a 2. If metals concentrations expected from mining operations were described as “low” or as not having significant increases over background/baseline concentrations, the entry was scored as a 1. For mines with multiple EISs, the EIS with the highest potential to generate contaminants was used as the score for the mine.

Table 5.11 shows the distribution and identity of mines in the four categories.

No Information Available

The EISs for 15 mines (21%) contained no information on contaminant leaching potential. These mines included two in Alaska, five (of eight) in Arizona, two fin California, one each in Idaho, Montana and New Mexico, and three in Nevada. Three of these mines (True North, AK; Royal Mountain King, CA (EIR-EA); Rain, NV) had EAs rather than EISs.

Low Contaminant Leaching Potential

An approximately equal number of mines had low (22 or 31%) and moderate (21 or 30%) contaminant leaching potential. Two of the mines in the low contaminant leaching potential category (East Boulder, Montana and Tyrone, New Mexico) did not perform short-term leach or kinetic tests (the East Boulder Mine also performed no static testing). In both cases, the low contaminant leaching potential was based on the low sulfur/sulfide content.

In fact, many of the mines in this category based the low contaminant leaching potential on predicted low acid generation potential. For those mines that did conduct contaminant leaching tests (e.g., short-term leach tests), results were variably compared to drinking water standards and standards for leach tests (e.g., soluble threshold levels for California; TCLP levels). In addition to the East Boulder, Montana, and Tyrone, New Mexico mines, five other mines in this category did not perform short-term leach tests (Fort Knox, AK : Mesquite, CA; Stibnite, ID; Basin Creek and Diamond Hill, MT). These five mines did perform kinetic tests, but metals were not always determined to have been analyzed in the leachate.

Table 5.11. Contaminant Leaching Potential

0		1		2		3	
No information available		Low		Moderate		High	
AJ Project	AK	Fort Knox	AK	Pogo Project	AK	Kensington Project	AK
True North	AK	Greens Creek*	AK	Carlotta	AZ	Red Dog	AK
Bagdad*	AZ	Safford (Dos Pobres)	AZ	McLaughlin*	CA	Beartrack	ID
Cyprus Tohono	AZ	Sanchez	AZ	Black Pine*	MT	Golden Sunlight*	MT
Morenci	AZ	American Girl*	CA	Mineral Hill*	MT	Rock Creek	MT
Ray*	AZ	Castle Mountain*	CA	Montanore	MT	Bald Mountain	NV
Yarnell	AZ	Hayden Hill	CA	Stillwater*	MT	Battle Mountain Phoenix	NV
Imperial	CA	Jamestown*	CA	Troy	MT	Cortez Pipeline	NV
Royal Mountain King*	CA	Mesquite*	CA	Zortman and Landusky*	MT	Gold Quarry	NV
Stone Cabin	ID	Black Pine	ID	Florida Canyon*	NV	Leeville	NV
Montana Tunnels	MT	Grouse Creek*	ID	Goldstrike	NV	Lone Tree*	NV
Copper Flat	NM	Stibnite	ID	Griffon	NV	Round Mountain*	NV
Cortez	NV	Thompson Creek*	ID	Jerritt Canyon*	NV	Twin Creeks*	NV
Dash	NV	Basin Creek	MT	Marigold	NV		
Rain	NV	Beal Mountain*	MT	Mule Canyon	NV		
		Diamond Hill	MT	Olinghouse	NV		
		East Boulder	MT	Pete	NV		
		Tyrone Little Rock	NM	Rochester*	NV		
		Austin Gold Venture	NV	Ruby Hill*	NV		
		Robinson (Ruth)	NV	Gilt Edge	SD		
		Trenton Canyon	NV	Flambeau*	WI		
		Lisbon Valley	UT				
	15		22		21		13

Low = leachate concentrations < water quality standards; Moderate = leachate exceeds water quality standards by 1 - 10 times; High = leachate exceeds water quality standards by > 10 times.

Moderate Contaminant Leaching Potential

Twenty-one mines (30%) identified had moderate contaminant leaching potential. Four of the mines in this category did not perform short-term leach or kinetic testing (Black Pine, Montanore, Troy, MT; Pete, NV). Two of the Montana mines based the moderate contaminant leaching potential on tailings water quality. The Goldstrike Mine in Nevada also did not perform short-term leach tests but did conduct kinetic testing.

High Contaminant Leaching Potential

Thirteen (18%) of the mines identified had high contaminant leaching potential (Kensington Project, AK; Beartrack, ID; Golden Sunlight and Rock Creek mines, MT; Bald Mountain, Battle Mountain Complex, Cortez Pipeline, Gold Quarry/Maggie Creek, Leeville, Lone Tree, Round Mountain and Twin Creeks, NV). Two of the mines in this category conducted no short-term leach tests (Rock Creek, MT; Gold Quarry/Maggie Creek, NV), but they did conduct kinetic testing.

Nevada had the highest percentage (75%) of mines with either moderate or high contaminant leaching potential (18/24 mines), followed by Montana with 62% (8/13 mines). Nevada also had a high percentage (75%) of mines conducting short-term leach tests (18/24 mines). California had the highest percentage (63%) of mines with low contaminant leaching potential (5/8 mines) and only one (McLaughlin) with moderate contaminant leaching potential. California also had a high percentage (75%) of mines conducting short-term leach tests (6/8 mines). Both states have short-term leach tests that were developed specifically for use in those states – the meteoric water mobility procedure (MWMP) for Nevada and the waste extraction test (CAL WET) test for California.

Of the 12 mines with high contaminant leaching potential, only three (Red Dog, AK; Golden Sunlight, MT; Battle Mountain Complex, NV) also identified high acid generation potential. Five mines (Kensington Project, AK; Beartrack, ID; Rock Creek, MT; Bald Mountain and Cortez Pipeline, NV) identified high contaminant leaching potential and low acid drainage potential.

5.6.3. POTENTIAL GROUNDWATER QUALITY IMPACTS

Groundwater impact potential refers to the proposed project's potential to adversely affect groundwater quality in the absence of mitigation measures. Section 5.7.1 describes the projects' predicted impact on groundwater after proposed mitigation measures were put in place. The information on groundwater quality impact potential was summarized and scored according to the following four categories:

- No information available (0)
- Low groundwater quality impacts (< relevant standards) (1)
- Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) (2)
- High groundwater quality impacts (>10 times relevant standards) (3)

For mines with multiple EISs, the EIS with the highest individual score for potential groundwater impacts was used as the score for the mine. Scores for potential groundwater impacts were often based on qualitative information or descriptions (e.g., "moderate" effects expected on groundwater quality). If an EIS entry noted anything regarding potential groundwater quality that was negative, it was scored as a 2 (moderate impacts). The EISs were also reviewed for any information on the potential for long-term groundwater quality impacts.

Table 5.12 lists the mines in the four categories for groundwater impact potential.

No Information Available

Fourteen (20%) of the 71 reviewed mines with EISs did not provide any information on groundwater quality impact potential. Four of these mines had EAs rather than EISs (Fort Knox and True North, AK; Basin Creek, MT; Pete, NV). Of the remaining 10 mines in this category, four were in Arizona, two in New Mexico, and one each was in Alaska, Idaho, Montana, and Nevada.

Low Groundwater Quality Impact Potential

At 19 mines (27%), the EISs identified low groundwater impact potential. Of these mines, one had high acid drainage potential, and four had high contaminant leaching potential. Nine of these 19 mines had shallow depths to groundwater or springs on site.

Moderate Groundwater Quality Impact Potential

The majority of the mines (33 or 47%) had moderate groundwater impact potential. Two of these mines had high acid drainage potential (Zortman and Landusky, MT; Battle Mountain Complex, NV), and five had high contaminant leaching potential (Rock Creek, MT; Battle Mountain Complex, Cortez Pipeline, Leeville, Twin Creeks, NV). Twenty-one of these 33 mines had close proximity to groundwater or springs on site.

Table 5.12. Groundwater Quality Impact Potential

0		1		2		3	
No information available		Low		Moderate		High	
AJ Project	AK	Kensington Project	AK	Greens Creek*	AK	Pogo Project	AK
Fort Knox	AK	Red Dog	AK	Carlotta	AZ	McLaughlin*	CA
True North	AK	Bagdad*	AZ	American Girl*	CA	Golden Sunlight*	MT
Morenci	AZ	Cyprus Tohono	AZ	Hayden Hill	CA	Florida Canyon*	NV
Ray*	AZ	Sanchez	AZ	Jamestown*	CA	Round Mountain*	NV
Safford (Dos Pobres)	AZ	Castle Mountain*	CA	Mesquite*	CA		
Yarnell	AZ	Imperial	CA	Royal Mountain King*	CA		
Beartrack	ID	Black Pine	ID	Grouse Creek*	ID		
Basin Creek	MT	Stone Cabin	ID	Stibnite	ID		
Black Pine*	MT	Diamond Hill	MT	Thompson Creek*	ID		
Copper Flat	NM	Stillwater*	MT	Beal Mountain*	MT		
Tyrone Little Rock	NM	Bald Mountain	NV	East Boulder	MT		
Griffon	NV	Cortez	NV	Mineral Hill*	MT		
Pete	NV	Gold Quarry	NV	Montana Tunnels	MT		
		Lone Tree*	NV	Montanore	MT		
		Mule Canyon	NV	Rock Creek	MT		
		Rain	NV	Troy	MT		
		Ruby Hill*	NV	Zortman and Landusky*	MT		
		Lisbon Valley	UT	Austin Gold Venture	NV		
				Battle Mountain Phoenix	NV		
				Cortez Pipeline	NV		
				Dash	NV		
				Goldstrike	NV		
				Jerritt Canyon*	NV		
				Leeville	NV		
				Marigold	NV		
				Olinghouse	NV		
				Robinson (Ruth)	NV		
				Rochester*	NV		
				Trenton Canyon	NV		
				Twin Creeks*	NV		
				Gilt Edge	SD		
				Flambeau*	WI		
	14		19		33		5

For potential impacts (without considering effect of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

High Groundwater Quality Impact Potential

Only five of the reviewed mines (7%) were identified as having a high potential for groundwater impact (Pogo Project, AK; McLaughlin, CA; Golden Sunlight, MT; Florida Canyon and Round Mountain, NV). Of these, only the Golden Sunlight Mine had high acid drainage and contaminant leaching potential. The Round Mountain Mine had high contaminant leaching potential but low acid drainage potential. The other mines in this category had low to moderate acid drainage and contaminant leaching potential.

Long-term Groundwater Quality Impacts

A number of mines mentioned that groundwater quality impacts would not occur until years in the future or that groundwater impacts would worsen with time. These delayed impacts often result from rising water levels in underground mines, cessation of groundwater pumping in open pit mines or movement of the wetting front through waste rock dumps or other unsaturated mine materials over time. At the Montana Tunnels mine, poor water quality was not expected to seep out of the pit and affect downgradient groundwater and surface water resources until 480 years after mining.

A number of other mine EISs mention long-term groundwater quality impacts. The 2003 EIS for the Pogo Project in Alaska stated that there is some potential for increased concentrations of contaminants downgradient of the mine over the long term (thousands of years) in excess of 10 times water quality standards.

The 2004 Draft EIS for the Golden Sunlight Mine in Montana noted that after mining, if the groundwater table rebounds to a static condition, fracture-controlled flow to surface seeps could increase and acid springs could develop again. They suggest that maintaining the pit as a hydrologic sink could minimize the risk of seep development. At the Montana Tunnels mine, poor water quality is not expected to seep out of the pit and affect downgradient groundwater and surface water resources until 480 years after mining. The EIS for the Montanore Mine in Montana noted that after water levels rise in the mine, discharge could occur from the adits or "along natural pathways."

Although the water is expected to be of relatively good quality, the EIS stated that the potential for acid drainage exists. The new project EIS for the Rock Creek Project in Montana noted that seepage from the proposed tailings impoundment to groundwater could approach several hundred gallons per minute by the end of the 30-year mine life, and that the long-term potential for acid drainage was unknown at this point. The EIS proposed a tailings seepage pumpback system to prevent changes in groundwater quality.

Modeling performed for the Battle Mountain Phoenix project in Nevada predicted that waste rock infiltration could degrade downgradient groundwater, and the potential for long-term impacts to groundwater quality existed during the post-closure period. They proposed a contingent long-term groundwater management plan to address these potential impacts. The 1991 EIS for the Goldstrike Project in Nevada stated that groundwater could be impacted by outflow from the pit once the pit reaches steady state conditions. The subsequent 2003 EIS stated that a pit lake was not expected to discharge to groundwater, but that water quality impacts were possible in areas affected by mine water management activities, including reinfiltration of dewatering water. Groundwater at the Rochester Mine in Nevada, which had two EAs, was predicted to be of good quality. The 2003 expansion EA for the Rochester Mine in Nevada stated that the Coeur operations or Relief Canyon operations near the Rochester Mine could generate long-term impacts to groundwater.

5.6.4. POTENTIAL SURFACE WATER QUALITY IMPACTS

Surface water impact potential refers to the proposed project's potential to adversely affect surface water quality in the absence of mitigation measures. Section 5.7.2 describes the project's predicted impact on surface water resources after proposed mitigation measures were put in place. The information on surface water quality impact potential was summarized and scored according to the following four categories:

- No information available (0)
- Low surface water quality impacts (< relevant standards) (1)
- Moderate surface water quality impacts (≥ and up to 10 times relevant standards) (2)
- High surface water quality impacts (>10 times relevant standards) (3)

For mines with multiple EISs, the EIS with the highest individual score for potential surface water impacts was used as the score for the mine. Scores for potential surface water impacts were often based on qualitative information or descriptions (e.g., no impacts expected on surface water quality). If an EIS entry noted anything regarding potential surface water quality that was negative, including a potential for sedimentation or erosion effects to surface water, it was scored as a 2 (moderate impacts). The EISs were also reviewed for any information on the potential for long-term surface water quality impacts and the effect of water quantity (e.g., groundwater pumping) on surface water resources.

Table 5.13 lists the mines that fall into the four categories for surface water impact potential.

Table 5.13. Surface Water Quality Impact Potential

0		1		2		3	
No information available		Low		Moderate		High	
AJ Project	AK	Kensington Project	AK	Greens Creek*	AK	Zortman and Landusky*	MT
Fort Knox	AK	Pogo Project	AK	Carlotta	AZ	Twin Creeks*	NV
Red Dog	AK	Bagdad*	AZ	Hayden Hill	CA		
True North	AK	Cyprus Tohono	AZ	Jamestown*	CA		
Morenci	AZ	Sanchez	AZ	McLaughlin*	CA		
Ray*	AZ	American Girl*	CA	Mesquite*	CA		
Safford (Dos Pobres)	AZ	Castle Mountain*	CA	Grouse Creek*	ID		
Yarnell	AZ	Imperial	CA	Stibnite	ID		
Royal Mountain King*	CA	Black Pine	ID	Thompson Creek*	ID		
Beartrack	ID	Stone Cabin	ID	Beal Mountain*	MT		
Basin Creek	MT	Diamond Hill	MT	Montana Tunnels	MT		
Black Pine*	MT	East Boulder	MT	Rock Creek	MT		
Montanore	MT	Golden Sunlight*	MT	Battle Mountain Phoenix	NV		
Copper Flat	NM	Mineral Hill*	MT	Dash	NV		
Tyrone Little Rock	NM	Stillwater*	MT	Goldstrike	NV		
Florida Canyon*	NV	Troy	MT	Griffon	NV		
Rain	NV	Austin Gold Venture	NV	Jerritt Canyon*	NV		
		Bald Mountain	NV	Leeville	NV		
		Cortez	NV	Lone Tree*	NV		
		Cortez Pipeline	NV	Marigold	NV		
		Gold Quarry	NV	Olinghouse	NV		
		Mule Canyon	NV	Pete	NV		
		Ruby Hill*	NV	Robinson (Ruth)	NV		
		Lisbon Valley	UT	Rochester*	NV		
				Round Mountain*	NV		
				Trenton Canyon	NV		
				Gilt Edge	SD		
				Flambeau*	WI		
	17		24		28		2

For potential impacts (without considering effect of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

No Information Available

Approximately one-quarter (17 or 24%) of the mines did not provide any information on the potential for surface water quality impacts. Mines in this category included two in Alaska, four in Arizona, one each in California and Idaho, three in Montana, two in New Mexico, and two in Nevada. Of these 18 mines, five had EAs rather than EISs (Fort Knox and True North, AK; Royal Mountain King, CA (EIR-EA); Basin Creek, MT; Rain, NV).

Low Surface Water Quality Impact Potential

Nearly equal numbers of mines were identified as having low (24 or 34%) and moderate (28 or 40%) potential for surface water quality impacts. Of the 24 mines with low potential for surface water quality impacts, one had high acid drainage and contaminant leaching potential (Golden Sunlight, Montana), and four others had high contaminant leaching potential (Kensington, AK; Bald Mountain, Cortez Pipeline, Gold Quarry/Maggie Creek, NV). For the two Golden Sunlight EISs with information on surface water quality impact potential, the low potential was attributed to: the lack of any perennial surface waters in close proximity of the proposed facilities (if clean-up efforts are prompt); the slow movement of the wetting front through the waste rock dumps; and run-on controls.

Six of the 24 mines with low surface water quality impact potential had perennial streams on site (Kensington and Pogo, AK; Stone Cabin, ID; East Boulder, Mineral Hill, and Troy, MT), and 11 were far from surface water resources (> one mile). Those mines with close proximity to surface water but low potential for impacts generally ascribed the low potential to dilution. In most cases, surface water quality was expected to have some impact from mining operations but was not predicted or expected to exceed relevant water quality standards in surface water. The Kensington Project in Alaska was expected to have low surface water quality impacts, even though it is close to surface water and has high contaminant leaching potential. The low potential at the Kensington Project was attributed to the low acid drainage potential and the observation that waste rock and tailings infiltration water quality is expected to be similar to background groundwater quality.

Moderate Surface Water Quality Impact Potential

Twenty-eight mines (40%) were identified as having moderate potential for surface water quality impacts. Of these 28 mines, one mine (Battle Mountain Phoenix, NV) had high potential for acid drainage and contaminant leaching. However, the closest perennial surface water is one mile from the facilities, and no offsite impacts to surface water were expected. Four other mines in this category had high contaminant leaching potential (Rock Creek, MT; Leeville, Lone Tree, Round Mountain, NV). The Rock Creek Project is also located close to surface water resources. The Rock Creek Project EIS acknowledged the potential impact to surface water quality of the mine facilities, but noted that water treatment, dilution, and groundwater pumping would help mitigate these impacts. The Lone Tree Mine is located two miles from the Humboldt River but discharges dewatering water to the Humboldt River. Water pumped from the ground and discharged into the Humboldt River was considered to generally be of good quality; however, the 1996 EIS did note recent increased concentrations of arsenic, iron, and sulfate in mine discharge water and aquatic life exceedences of iron, copper and lead in the discharge water. The Leeville Mine proposed to discharge dewatering water to reinfiltration basins and also to the Humboldt River if that does not provide sufficient volume, and discharge water did not meet the arsenic drinking water standard. Round Mountain has no perennial streams on site.

High Surface Water Quality Impact Potential

Only two of the reviewed mines were identified as having a high potential for surface water impacts (Zortman and Landusky, MT; Twin Creeks, NV). The 1993 Supplemental EA for the Zortman and Landusky Mine noted that existing water quality in Mill Gulch and upper Sullivan Creek has already become acidic as a result of waste rock and leach pad leachate. Similarly, surface water at the Twin Creeks Mine had already shown occasional exceedences of total dissolved solids and arsenic (arsenic by over 10 times the 10-µg/l drinking water standard) as a result of discharge of dewatering water in Rabbit Creek.

Long-term Surface Water Quality Impact Potential

A number of EIS mentioned the effect of time on potential impacts to surface water resources as a result of mining operations. The 1997 EIS for the Golden Sunlight Mine in Montana noted that slow movement of the wetting front through waste rock and run-on controls could limit potential migration of acid drainage to surface water. This same mechanism could delay impacts of acid drainage to surface water. The Montana Tunnels Mine EIS, as noted earlier, stated that poor-quality water was not expected to seep out of the pit until hydrologic equilibrium was reached in

480 years. At this time, no more than 15 gpm was expected to flow out of the pit toward Spring Creek. Contaminants in the pit seepage water were expected to be diluted and retarded in groundwater, and the impact on Spring Creek water quality was stated as unknown. The 1995 EIS for the Rock Creek Mine in Montana noted that the long-term potential for acid drainage was unknown, and the 2001 EIS noted that if there is outflow of mine adit water, perpetual treatment might be required prior to discharge to the Clark Fork River.

The 1984 Grouse Creek, Idaho, EIS mentioned that water quality changes in surface streams were predicted to be of short duration. Modeling conducted (PYROX modeling of tailings) for the 1999 Thompson Creek, Idaho, EIS concluded that potential impacts to water quality in Squaw Creek should be reduced as a result of excess neutralization capacity at the end of the 100-year period.

Water Quantity Effects

Several EISs mentioned potential water quantity effects on surface water resources. Most of these potential impacts were related to groundwater pumping for dewatering operations and excavation of underground workings. The 2001 EIS for the Rock Creek Project in Montana concluded that water levels in and groundwater inflow to several wilderness lakes overlying the mined-out portions of the underground mine could potentially be reduced if faults or fractures acted as groundwater conduits and grouting programs were ineffective. The 1995 Bald Mountain, Nevada, EIS acknowledged the potential for reduced flow in the Cherry Creek Spring as a result of dewatering operations. Similarly, the Battle Mountain, Nevada, EIS noted that dewatering operations could reduce flow in perennial streams and springs. The 2003 Goldstrike, Nevada, EIS concluded that the primary issue related to the quality of surface water was degraded stream water quality resulting from dewatering operations. Based on hydrologic modeling results, there was some recognized potential for additional flow reductions to perennial water sources in localized areas from future mine-induced drawdown. Finally, the Marigold, Nevada, 2001 EIS stated that groundwater pumping or drainage modification could cause reduction in surface water flows and impacts to riparian or wetland areas.

5.6.5. POTENTIAL PIT WATER IMPACTS

Pit water impact potential refers to the proposed project's potential to adversely affect water quality in the pit in the absence of mitigation measures. Water in the pit refers to either pit lake water or water associated in the interstices of pit backfill material. Section 5.7.3 describes the projects' predicted impact on pit water quality after proposed mitigation measures were put in place. The information on pit water quality impact potential was summarized and scored according to the following five categories:

- No information available (0)
- Low pit water quality impacts (water quality similar to surrounding groundwater or < relevant standards) (1)
- Moderate pit water quality impacts (≥ and up to 10 times relevant standards) (2)
- High pit water quality impacts (>10 times water quality standards) (3)
- No pit lake or long-term standing water expected (pit above water table or no pit) (4)

For mines with multiple EISs, the EIS with the highest individual score for potential pit water impacts was used as the score for the mine. Scores for potential pit water impacts were often based on qualitative information or descriptions (e.g., pit water quality expected to be poor). If an EIS entry noted anything regarding potential pit water quality that was negative, it was scored as a 2 (moderate impacts). If the pit was proposed to be backfilled but the EIS did not address backfill water quality, it was scored as a 0. For mines with multiple proposed pits above the water table, the pit with the highest score (1, 2, or 3) was used to score the mine as a whole. Information on long-term pit water quality impacts is also discussed.

Table 5.14 lists the mines that fall into the five categories for potential pit water quality impacts.

Table 5.14. Pit Water Quality Impact Potential

0		1		2		3		4	
No information available		Low		Moderate		High		No pit lake expected to form (pit above water table or no pit)	
Fort Knox	AK	Bagdad*	AZ	Sanchez	AZ	Safford (Dos Pobres)	AZ	AJ Project	AK
Red Dog	AK	Castle Mountain*	CA	Jamestown*	CA	McLaughlin*	CA	Greens Creek*	AK
True North	AK	Imperial	CA	Mesquite*	CA	Golden Sunlight*	MT	Kensington Project	AK
Carlotta	AZ	Black Pine	ID	Beartrack	ID	Montana Tunnels	MT	Pogo Project	AK
Morenci	AZ	Stone Cabin	ID	Grouse Creek*	ID	Gold Quarry	NV	Cyprus Tohono	AZ
Ray*	AZ	Basin Creek	MT	Thompson Creek*	ID	Goldstrike	NV	Hayden Hill	CA
Yarnell	AZ	Tyrone Little Rock	NM	Cortez Pipeline	NV	Lone Tree*	NV	Diamond Hill	MT
American Girl*	CA			Marigold	NV	Twin Creeks*	NV	East Boulder	MT
Royal Mountain King*	CA			Mule Canyon	NV	Lisbon Valley	UT	Mineral Hill*	MT
Stibnite	ID			Olinghouse	NV	Flambeau*	WI	Montanore	MT
Beal Mountain*	MT			Robinson (Ruth)	NV			Rock Creek	MT
Black Pine*	MT			Round Mountain*	NV			Stillwater*	MT
Zortman and Landusky*	MT			Gilt Edge	SD			Troy	MT
Copper Flat	NM							Bald Mountain	NV
Austin Gold Venture	NV							Cortez	NV
Battle Mountain Phoenix	NV							Griffon	NV
Dash	NV							Jerritt Canyon*	NV
Florida Canyon*	NV							Leeville	NV
Pete	NV							Rain	NV
								Rochester*	NV
								Ruby Hill*	NV
								Trenton Canyon	NV
	19		7		13		10		22

For potential impacts (without considering effect of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

No Information Available

A high proportion of the mines with proposed open pits that were expected to contain water (19 or 27%) did not provide information on potential pit water quality impacts. Of these, four had EAs rather than EISs (Fort Knox and True North, AK; Royal Mountain King, CA (EIR-EA); Austin Gold Venture, NV), and two were land-exchange EISs (Morenci and Ray, AZ). Of the remaining 13 mines, two were in Arizona, one each was in Alaska, California, Idaho and New Mexico, three were in Montana and four were in Nevada.

Low Pit Water Quality Impact Potential

Seven (10%) of the mines identified low potential for pit water quality impacts. The majority of these mines ascribed the low impact potential for impact to low acid drainage and/or contaminant leaching potential of rocks within the pit. None of these mines identified a high potential for either acid drainage or contaminant leaching.

Moderate Pit Water Quality Impact Potential

Moderate pit water quality impacts were identified for 13 (18%) of the 71 NEPA mines. Of these, the EIS for the Beartrack, Idaho mine had high contaminant leaching potential. The EIS for the Round Mountain Mine and the Cortez Pipeline mines in Nevada identified moderate acid drainage potential. The potential for moderate pit water quality impacts was generally ascribed to increased concentrations from evapoconcentration and the presence of materials with elevated acid-generating and/or contaminant leaching potential within the pit. In some cases, future water quality in the pits was based on observed water quality in existing pits at the site.

High Pit Water Quality Impact Potential

Ten (14%) of the mines were identified as having a high potential for pit water quality impacts, including the McLaughlin Mine in California, the Golden Sunlight and Montana Tunnels mines in Montana, and the Flambeau Mine (with a backfilled pit) in Wisconsin. The Golden Sunlight Mine identified high acid drainage and contaminant leaching potential, and the Gold Quarry/Maggie Creek, Lone Tree, Cortez Pipeline and Twin Creeks mines in Nevada identified high contaminant leaching potential. The majority (seven) of these 10 mines conducted both water quantity and quality modeling to predict pit water quality. The Flambeau Mine conducted only water quality modeling of the pit backfill leachate and predicted that manganese concentrations would be over 10 times drinking water standards.

No Pit Lake or Water Expected

Twenty-two (31%) of the mines were not expecting water in the pit either because the pit was above the water table or it was a proposed underground mine. Even when the bottom of a pit may be above the water table, seasonal water can still collect in the pit. In a number of these instances, remedial measures were proposed to avoid accumulation of pit water (see Section 5.6.3). Of the 22 mines, all the mines in Alaska and Montana and the Leeville Mine in Nevada are underground mines; all the other listed mines in this category are open pit mines with pit bottoms expected to be above the water table.

Long-term Pit Water Quality Impacts

EISs for several mines discussed the potential impact of time on pit water quality. The pit water at the Montana Tunnels Mine in Montana (as noted earlier in the section on potential groundwater quality impacts) was expected to become acidic and discharge to groundwater after 480 years. Pit water in the Cortez Pipeline Mine in Nevada was expected to exceed Nevada drinking water standards for pH (elevated pH), fluoride, sulfate, cadmium, manganese, mercury silver, and total dissolved solids at 250 years post closure. The Lone Tree, Nevada, open pit water quality was expected to be acidic initially, become neutral after 10 years and exceed drinking water standards for arsenic (until 10 years post-closure, then not exceed), cadmium (for one year only), nickel, fluoride, antimony (after 25 years) and sulfate (until 10 years). Nickel and fluoride concentrations were expected to exceed water quality standards by less than 10 times, but antimony concentrations are expected to be over 10 times higher than standards. The EIS for the Robinson (Ruth) Mine in Nevada stated that some improvement in pit (Liberty and Ruth pits) water quality could be expected as mineralization is removed by mining. The EIS also noted that pit dewatering and subsequent refilling would result in improved pit water quality because acidic solutions were discharged into the pit during historic leaching activities.

5.7. PROPOSED MITIGATION

EISs may analyze and subsequent Records of Decision (ROD) may require mitigation to address potential water quality impacts that are identified in the EISs. Mitigation are commonly designed for the protection of groundwater and surface water resources and may address pit water quality (depending on state requirements).

Mitigation include pollution prevention measures and abatement measures. Pollution prevention measures aim to control pollution at its source and include liners, special handling of potentially acid-generating (PAG) waste, adit plugging, leak-detection systems, and caps and covers. Abatement measures are designed to mitigate pollution after it has been created and include capture, treatment and discharge of contaminated water, or in some cases may require replacement measures (such as for water quantity). They may also be short-term (e.g., during the operational life of the project) or long-term (e.g., perpetual water treatment and/or site maintenance).

In many cases, the EISs reviewed described mitigation that would be included in the mine plan “if necessary.” Many EISs described measures to prevent or mitigate the impacts of acid drainage, including: isolation, segregation, or amendment of acid-generating wastes; and capture and treatment of acid drainage. The mitigation identified in EISs were for proposed projects or expansions of existing projects and are therefore proposed rather than actual mitigation. The mitigation that are actually implemented will depend on a number of factors and are often contained as requirements in the ROD after the mine is permitted. However, the proposed mitigation discussed in this section are an important part of the NEPA process because they respond to the identified potential impacts. In many cases they determine, or are depended upon to bring about, the predicted or post-mitigation, impacts (e.g., liners used for potential cyanide contamination leading to prediction of no or acceptable contamination).

Water-quality mitigation identified in the EISs fell into groundwater, surface water, and pit water measures. For mines that proposed treatment as part of the mitigation measures, the type of treatment was also categorized and scored.

5.7.1. PROPOSED GROUNDWATER MITIGATION

The information on groundwater mitigation contained in the EISs was summarized and scored according to one or more of the following categories:

- No information available or no mitigation identified (0)
- Groundwater monitoring or characterization of mined materials (1)
- Source controls without treatment (liners, leak detection systems, run on/off controls, caps/covers, adit plugging) (2)
- Groundwater/leachate capture with treatment (3)
- Perpetual groundwater capture and/or treatment; long-term mitigation fund (4)
- Liming, blending, segregation, etc. of potentially acid-generating (PAG) material (5)

Table 5.15 lists the mines with proposed groundwater mitigation that fell into the six categories.

No Information Available or No Mitigation Identified

Twelve (17%) of the 71 NEPA mines did not identify any type of groundwater mitigation.

Groundwater Monitoring or Characterization of Mined Materials

Nearly half of the mines (33, or 46%) proposed groundwater monitoring or materials characterization as a type of groundwater mitigation. Monitoring and characterization do not directly mitigate impacts to groundwater, but results of these tests can be used to identify the need for mitigation after the facility is in operation.

Table 5.15. Proposed Groundwater Mitigation

0		1		2		3		4		5	
No information available		Monitoring or characterization		Source controls without treatment		Groundwater/leachate capture		In-perpetuity capture and/or treatment; long-term fund		Liming, blending, segregation, etc. of PAG material	
AJ Project	AK	Carlotta	AZ	Kensington Project	AK	Greens Creek*	AK	Golden Sunlight*	MT	Greens Creek*	AK
Fort Knox	AK	Morenci	AZ	Pogo Project	AK	Kensington Project	AK	Rock Creek	MT	Pogo Project	AK
True North	AK	Safford	AZ	Red Dog	AK	Pogo Project	AK	Goldstrike	NV	Grouse Creek*	ID
Bagdad*	AZ	Hayden Hill	CA	Carlotta	AZ	Red Dog	AK			Stone Cabin	ID
Ray*	AZ	Jamestown*	CA	Cyprus Tohono	AZ	Castle Mountain*	CA			Beal Mountain*	MT
Royal Mountain King*	CA	McLaughlin*	CA	Morenci	AZ	Hayden Hill	CA			Diamond Hill	MT
Stone Cabin	ID	Mesquite*	CA	Safford	AZ	Jamestown*	CA			Montanore	MT
Basin Creek	MT	Beartrack	ID	Sanchez	AZ	Mesquite*	CA			Zortman Landusky*	MT
Troy	MT	Black Pine	ID	Yarnell	AZ	Thompson Creek*	ID			Florida Canyon*	NV
Rochester*	NV	Grouse Creek*	ID	American Girl*	CA	Golden Sunlight*	MT			Jerritt Canyon*	NV
Trenton Canyon	NV	Stibnite	ID	Castle Mountain*	CA	Mineral Hill*	MT			Leeville	NV
Copper Flat	NM	Thompson Creek*	ID	Hayden Hill	CA	Montana Tunnels	MT			Marigold	NV
		Beal Mountain*	MT	Imperial	CA	Rock Creek	MT			Twin Creeks*	NV
		Golden Sunlight*	MT	Jamestown*	CA	Stillwater*	MT				
		Montanore	MT	Mesquite*	CA	Zortman Landusky*	MT				
		Rock Creek	MT	Beartrack	ID	Austin Gold Venture	NV				
		Stillwater*	MT	Black Pine	ID	Phoenix	NV				
		Zortman Landusky*	MT	Grouse Creek*	ID	Cortez	NV				
		Austin Gold Venture	NV	Stibnite	ID	Cortez Pipeline	NV				
		Bald Mountain	NV	Thompson Creek*	ID	Gold Quarry	NV				
		Phoenix	NV	Beal Mountain*	MT	Goldstrike	NV				
		Cortez	NV	Black Pine*	MT	Leeville	NV				
		Cortez Pipeline	NV	East Boulder	MT	Lone Tree*	NV				
		Dash	NV	Golden Sunlight*	MT	Pete	NV				
		Gold Quarry	NV	Montana Tunnels	MT	Rain	NV				
		Goldstrike	NV	Montanore	MT	Robinson (Ruth)	NV				
		Lone Tree*	NV	Stillwater*	MT	Flambeau*	WI				
		Marigold	NV	Zortman Landusky*	MT						
		Mule Canyon	NV	Venture	NV						
		Pete	NV	Bald Mountain	NV						
		Rain	NV	Battle Mountain Phoenix	NV						
		Robinson (Ruth)	NV	Cortez	NV						
		Twin Creeks	NV	Cortez Pipeline	NV						
		Lisbon Valley Copper	UT	Florida Canyon*	NV						
				Gold Quarry	NV						
				Griffon	NV						
				Jerritt Canyon*	NV						
				Leeville	NV						
				Marigold	NV						
				Olinghouse	NV						
				Pete	NV						
				Rain	NV						
				Robinson (Ruth)	NV						
				Round Mountain*	NV						
				Ruby Hill*	NV						
				Twin Creeks*	NV						
				Tyrone - Little Rock	NM						
				Gilt Edge	SD						
				Copper	UT						
				Flambeau*	WI						
	12		33		50		27		3		13

Source Controls Without Treatment (liners, leak detection systems, run on/off controls, caps/covers, adit plugging)

The majority of the mines (50, or 70%) proposed source controls without treatment to protect groundwater. The majority of these measures consisted of liners for tailings impoundments and heap leach operations to prevent groundwater contamination ("zero discharge" facilities).

Groundwater/Leachate Capture with Treatment

Approximately one-third (27 or 38%) of the mines proposed groundwater or leachate capture, either with or without treatment.

Perpetual Groundwater Capture and/or Treatment; Long-term Mitigation Fund

Only three of the mines (4%) (Rock Creek and Golden Sunlight, MT; Goldstrike (Betze), NV) mentioned in perpetuity capture and/or treatment or other type of long-term groundwater mitigation. For Rock Creek and Goldstrike, perpetual treatment or maintenance was identified as a possible long-term option if necessary, and the Goldstrike Mine proposed a $250,000 fund to cover monitoring costs beyond the year 2030 (in a 1991 EIS), and a $1,000,000 fund for the review, monitoring, and mitigation of impacts directly associated with the project, but not specifically identified in the EIS. Seepage from tailings and waste rock at the Golden Sunlight Mine in Montana, however, was expected in the 1997 EIS to require perpetual treatment.

The three mines, where EISs identified groundwater capture and treatment mitigation requirements, collected and treated acid drainage from beneath waste dumps, dewatered tailings or tailings leachate.

Liming, Blending, Segregation, etc. of Potentially Acid-Generating (PAG) Material

Thirteen (18%) of the mines identified special handling of PAG waste as a groundwater mitigation measure.

5.7.2. PROPOSED SURFACE WATER MITIGATION

The information on surface water mitigation contained in the EISs was summarized and scored according to the following categories:

- No information available or no mitigation identified (0)
- Surface water monitoring (1)
- Stormwater, sediment, or erosion controls (2)
- Source controls not involving capture of water (including liners, adit plugging, caps/covers, leak detection systems, spill prevention measures and liming/blending/segregating of PAG materials) (3);
- Surface water/leachate capture and/or treatment (including settling, land application, routing of water, seepage collection) (4)
- Perpetual surface water capture and/or treatment (5)
- Surface water augmentation or replacement (6)

Table 5.16 lists the mines with mitigation that fell into the seven categories.

No Information Available or No Mitigation Identified

The EISs for eleven mines (15%) contained no information on surface water mitigation.

Table 5.16. Proposed Surface Water Mitigation

0		1		2		3		4		5		6	
No information available		Monitoring or characterization		Stormwater/sediment/erosion controls		Source controls without water capture		Surface water/leachate capture/treatment		In-perpetuity capture/treatment		Surface water augmentation/ replacement	
AJ Project	AK	Castle Mountain*	CA	Greens Creek*	AK	Kensington	AK	Greens Creek *	AK	Rock Creek	MT	Golden Sunlight*	MT
Fort Knox	AK	Hayden Hill	CA	Kensington Project	AK	Bagdad*	AZ	Kensington Project	AK	Zortman Landusky*	MT	Goldstrike	NV
Red Dog	AK	Jamestown*	CA	Pogo Project	AK	Morenci	AZ	Pogo Project	AK				
True North	AK	Mesquite*	CA	Red Dog-	AK	Sanchez	AZ	Yarnell	AZ				
Ray*	AZ	Grouse Creek*	ID	Bagdad*	AZ	American Girl*	CA	Jamestown*	CA				
Basin Creek	MT	Thompson	ID	Carlotta	AZ	Castle Mountain*	CA	McLaughlin*	CA				
East Boulder	MT	Black Pine*	MT	Cyprus Tohono	AZ	Imperial	CA	Stibnite	ID				
Mineral Hill*	MT	Rock Creek	MT	Morenci	AZ	Jamestown*	CA	Stone Cabin	ID				
Troy	MT	Stillwater*	MT	Safford (Dos	AZ	McLaughlin*	CA	Thompson Creek*	ID				
Copper Flat	NM	Zortman Landusky*	MT	Sanchez	AZ	Mesquite*	CA	Diamond Hill	MT				
Gilt Edge	SD	Dash	NV	Yarnell	AZ	Beartrack	ID	Golden Sunlight*	MT				
		Gold Quarry	NV	American Girl*	CA	Grouse Creek*	ID	Rock Creek	MT				
		Goldstrike	NV	Castle Mountain*	CA	Stibnite	ID	Zortman Landusky*	MT				
		Twin Creeks*	NV	Imperial	CA	Beal Mountain*	MT	Bald Mountain	NV				
				Jamestown*	CA	Black Pine*	MT	Gold Quarry	NV				
				McLaughlin*	CA	Rock Creek	MT	Jerritt Canyon*	NV				
				Mesquite*	CA	Stillwater*	MT	Marigold	NV				
				Royal Mountain King*	CA	Zortman Landusky*	MT	Rain	NV				
				Beartrack	ID	Bald Mountain	NV	Robinson (Ruth)	NV				
				Black Pine	ID	Battle Mountain	NV	Tyrone - Little	NM				
				Grouse Creek*	ID	Cortez	NV	Flambeau*	WI				
				Stibnite	ID	Cortez Pipeline	NV						
				Beal Mountain*	MT	Dash	NV						
				Black Pine*	MT	Florida Canyon*	NV						
				Montana Tunnels	MT	Jerritt Canyon*	NV						
				Montanore	MT	Lone Tree*	NV						
				Stillwater*	MT	Marigold	NV						
				Zortman Landusky*	MT	Pete	NV						
				Austin Gold	NV	Round Mountain*	NV						
				Bald Mountain	NV	Tyrone - Little	NM						
				Battle Mountain	NV	Lisbon Valley	UT						
				Cortez	NV	Flambeau*	WI						
				Dash	NV								
				Goldstrike	NV								
				Griffon	NV								
				Jerritt Canyon*	NV								
				Leeville	NV								
				Lone Tree*	NV								
				Marigold	NV								
				Mule Canyon	NV								
				Olinghouse	NV								
				Rain	NV								
				Robinson (Ruth)	NV								
				Rochester*	NV								
				Round Mountain*	NV								
				Ruby Hill*	NV								
				Trenton Canyon	NV								
				Twin Creeks*	NV								
				Lisbon Valley Copper	UT								
	11		14		49		32		21		2		0

Surface Water Monitoring

Fourteen (20%) of the mines identified monitoring as one of the proposed surface water mitigation.

Stormwater, Sediment or Erosion Controls

The largest number of mines (49 or 69%) proposed stormwater, sediment or erosion controls.

Source Controls Not Involving Capture of Water (including liners, adit plugging, caps/covers, leak detection systems, spill prevention measures and liming/blending/segregating of PAG materials)

Thirty two (45%) of the mines proposed source controls to protect surface water that included capping of dumps and tailings, stabilization measures, spill prevention measures and removal actions.

Surface Water/Leachate Capture and/or Treatment (including settling, land application, routing of water, seepage collection)

Nearly one-third of the mines (21 or 30%) proposed surface water or leachate capture and/or treatment as a surface water mitigation measure.

In Perpetuity Surface Water Capture and/or Treatment

Only two mines, (Rock Creek and Zortman and Landusky, MT) mentioned the possibility of perpetual treatment of surface water. In the case of Rock Creek it applies to the treatment of water discharging to the surface from the underground mine after plugging, if necessary, before the water is discharged to the Clark Fork River.

Surface Water Augmentation or Replacement

Only two mines mentioned the possibility of replacing or augmenting surface water: the Golden Sunlight Mine in Montana proposed supplying water sources for wildlife if the supply and quality of springs deteriorated; and the Goldstrike (Betze) Mine in Nevada proposed replacing or augmenting perennial surface flows if they were lost or decrease as a result of dewatering activities.

5.7.3. PROPOSED PIT WATER MITIGATION

The information on pit water mitigation contained in the EISs was summarized and scored according to one or more of the following categories:

- No information provided or none identified (0)
- Pit lake monitoring (1)
- Pit lake prevention (backfill, pumping, stormwater diversion, use in mine operation) (2)
- Treatment of pit water or backfill amendment (e.g., lime addition) (3)
- Not applicable: no pit lake will form (underground mine or pit above water table) (4)
- Contingency or research fund for pit lake, adaptive management (5)

Table 5.17 lists the mines with pit water mitigation that fell into the six categories.

No Information Provided or None Identified

Approximately one-quarter (19 or 27%) of the mines had no information on pit water quality mitigation; all of these mines had proposed open pits.

Table 5.17. Proposed Pit Water Mitigation

0		1		2		3		4		5	
No information available		Pit lake monitoring		Pit lake prevention (backfill, pumping, stormwater diversion, use in mine operation)		Treatment of pit water or backfill amendment (e.g. lime addition)		Not Applicable: no pit lake will form (underground mine or pit above water table)		Contingency or research fund for pit lake; adaptive management	
Fort Knox	AK	Castle Mountain*	CA	Bagdad*	AZ	Hayden Hill	CA	AJ Project	AK	Pipeline	NV
True North	AK	Grouse Creek*	ID	Carlotta	AZ	Stibnite	ID	Greens Creek*	AK	Goldstrike	NV
Red Dog	AK	Goldstrike	NV	Cyprus Tohono	AZ	Golden Sunlight*	MT	Kensington Project	AK		
Morenci	AZ	Round Mountain*	NV	Safford (Dos Pobres/San	AZ	Battle Mountain Phoenix	NV	Pogo Project	AK		
Ray*	AZ	Twin Creeks*	NV	Sanchez	AZ	Marigold	NV	American Girl*	CA		
Jamestown*	CA	Lisbon Valley Copper	UT	Yarnell	AZ	Flambeau*	WI	Black Pine*	MT		
McLaughlin*	CA			Castle Mountain*	CA			Diamond Hill	MT		
Mesquite*	CA			Hayden Hill	CA			East Boulder	MT		
Royal Mountain King*	CA			Imperial	CA			Mineral Hill*	MT		
Beartrack	ID			Black Pine	ID			Montanore	MT		
Thompson	ID			Grouse Creek*	ID			Rock Creek	MT		
Montana Tunnels	MT			Stibnite	ID			Stillwater*	MT		
Venture	NV			Stone Cabin	ID			Troy	MT		
Cortez	NV			Basin Creek	MT			Bald Mountain	NV		
Gold Quarry/ Maggie Creek	NV			Beal Mountain*	MT			Griffon	NV		
Mule Canyon	NV			Golden Sunlight*	MT			Jerritt Canyon*	NV		
Olinghouse	NV			Zortman	MT			Leeville	NV		
Robinson (Ruth)	NV			Bald Mountain	NV			Marigold	NV		
Copper Flat	NM			Phoenix	NV			Pete	NV		
				Dash	NV			Rain	NV		
				Florida Canyon*	NV			Rochester*	NV		
				Jerritt Canyon*	NV			Ruby Hill*	NV		
				Lone Tree*	NV			Trenton Canyon	NV		
				Marigold	NV						
				Pete	NV						
				Tyrone - Little	NM						
				Gilt Edge	SD						
				Flambeau*	WI						
	19		6		28		6		23		2

Pit Lake Monitoring

Monitoring of pit water quality was proposed at six (8%) of the mines. At two of these mines (Round Mountain and Twin Creeks) no other type of pit water quality mitigation was proposed.

Pit Lake Prevention (backfill, pumping, stormwater diversion, use in mine operation)

Pit lake prevention was identified at 28 (39%) of the mines; pit lake prevention measures included backfilling, pumping to prevent pit lake formation, stormwater diversion and use of pit water elsewhere in the mining operation.

Treatment of Pit Water or Backfill Amendment (e.g., lime addition)

Treatment of pit water or backfill amendment (e.g., lime addition) was identified at six (8%) of the mines.

Not Applicable: No Pit Lake Will Form (underground mine or pit above water table)

At approximately one-third (23 or 32%) of the 71 mines, no pit lake was expected to form, either because the mine was an underground mine or the bottom of the pit was above the water table.

Contingency or Research Fund for Pit Lake, Adaptive Management

At two of the mines, a contingency fund or research fund was proposed to address potential issues related to pit water quality. The Cortez Pipeline Mine in Nevada proposed adaptive management, because no mitigation measures appeared to be feasible for long-term potential environmental impacts and a contingency fund for monitoring and corrective action, should any be necessary. At the Goldstrike (Betze) Mine in Nevada, Barrick proposed to contribute $50,000 yearly, for a maximum of 10 years, to a college or university for conducting research related to water quality at inactive open pit mines.

5.7.4. PROPOSED WATER TREATMENT

The information on water treatment measures contained in the EISs was summarized and scored according to the following categories:

- No information provided or no water treatment measures identified (0)
- Solids or sediment settling ponds (1)
- Water treatment for cyanide (2)
- Water treatment for metals and/or acid drainage (3)
- Water treatment using non-conventional approaches (4)
- Perpetual water treatment (5)

Table 5.18 lists the mines with water treatment that fell into the six categories.

No Information Provided or No Water Treatment Measures Identified

Forty-eight (68%) of the mines provided no information on water treatment or no water treatment was proposed.

Solids or Sediment Settling Ponds

Six (8%) of the mines proposed settling of solids or sediment as a treatment method.

Water Treatment for Cyanide

Six (8%) of the mines proposed treatment for cyanide.

Water Treatment for Metals and/or Acid Drainage

Treatment for metals and/or acid drainage was proposed at 16 (23%) of the 71 NEPA mines.

Water Treatment Using Non-Conventional Approaches

Other types of treatment, including biological, land application, and passive approaches were proposed at 11 (15%) of the mines.

Water Treatment in Perpetuity

Perpetual treatment was specifically proposed, if necessary, at only four mines (Grouse Creek, ID; Golden Sunlight, Rock Creek and Zortman Landusky, MT).

Table 5.18. Proposed Water Treatment

0		1		2		3		4		5	
No information available/No treatment measures identified		Solids or sediment settling ponds		Water treatment for cyanide		Water treatment for metals and/or acid drainage		Water treatment using non-conventional approaches		Perpetual water treatment	
AJ Project	AK	Kensington Project	AK	Kensington Project	AK	Greens Creek*	AK	Beartrack	ID	Grouse Creek*	ID
Fort Knox	AK	Mineral Hill*	MT	Jamestown*	CA	Kensington Project	AK	Stibnite	ID	Golden Sunlight*	MT
True North	AK	Rock Creek	MT	Grouse Creek*	ID	Pogo Project	AK	Stone Cabin	ID	Rock Creek	MT
Bagdad*	AZ	Stillwater*	MT	Beal Mountain*	MT	Red Dog	AK	East Boulder	MT	Zortman and Landusky*	MT
Carlotta	AZ	Cortez Pipeline	NV	Lone Tree*	NV	Grouse Creek*	ID	Golden Sunlight*	MT		
Cyprus Tohono	AZ	Goldstrike	NV	Zortman and Landusky*	MT	Stone Cabin	ID	Mineral Hill*	MT		
Morenci	AZ					Golden Sunlight*	MT	Montanore	MT		
Ray*	AZ					Mineral Hill*	MT	Rock Creek	MT		
Safford	AZ					Montanore	MT	Stillwater*	MT		
Sanchez	AZ					Rock Creek	MT	Zortman and Landusky*	MT		
Yarnell	AZ					Zortman and Landusky*	MT	Lone Tree*	NV		
American Girl*	CA					Battle Mountain Phoenix	NV				
Castle Mountain*	CA					Goldstrike	NV				
Hayden Hill	CA					Lone Tree*	NV				
Imperial	CA					Twin Creeks*	NV				
McLaughlin*	CA					Flambeau*	WI				
Mesquite*	CA										
Royal Mountain King*	CA										
Black Pine	ID										
Thompson Creek*	ID										
Basin Creek	MT										
Black Pine*	MT										
Diamond Hill	MT										

Table 5.18. Proposed Water Treatment (Cont.).

0		1		2		3		4		5	
No information available/No treatment measures identified		Solids or sediment settling ponds		Water treatment for cyanide		Water treatment for metals and/or acid drainage		Water treatment using non-conventional approaches		Perpetual water treatment	
Montana Tunnels	MT										
Troy	MT										
Austin Gold Venture	NV										
Bald Mountain	NV										
Cortez	NV										
Dash	NV										
Florida Canyon*	NV										
Gold Quarry	NV										
Griffon	NV										
Jerritt Canyon*	NV										
Leeville	NV										
Marigold	NV										
Mule Canyon	NV										
Olinghouse	NV										
Pete	NV										
Rain	NV										
Robinson (Ruth)	NV										
Rochester*	NV										
Round Mountain*	NV										
Ruby Hill*	NV										
Trenton Canyon	NV										
Copper Flat	NM										
Tyrone-Little Rock	NM										
Gilt Edge	SD										
Lisbon Valley Copper	UT										
	48		6		6		16		11		4

5.8. PREDICTED WATER QUALITY IMPACTS

As noted in Section 5.5, this study distinguishes between potential and predicted water quality impacts. A predicted water quality impact is one that could occur after mitigation are in place. Predicted, or post-mitigation, impacts are considered by regulators when evaluating whether a proposed mine will meet applicable water quality standards. If a project predicts that waters of the state will not meet relevant standards as a result of the proposed activities, it is unlikely that the project will be approved. In general, very few EISs predicted that surface water and groundwater quality standards would not be met after mitigation were in place. Pit waters, on the other hand, are often not considered a water of the state, and under those conditions they are not necessarily required to meet Clean Water Act or Safe Drinking Water Act standards or criteria.

The elements of predicted water quality impacts reviewed in the 71 NEPA mine EISs include groundwater, surface water and pit water quality impacts.

5.8.1. PREDICTED GROUNDWATER QUALITY IMPACTS

The information on predicted groundwater quality impacts contained in the EISs was summarized and scored according to the following four categories:

- No information available (0)
- Low groundwater quality impacts (< relevant standards) (1)
- Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) (2)
- High groundwater quality impacts (>10 times relevant standards) (3)

For mines with multiple EISs, the EIS with the highest individual score for predicted groundwater impacts was used as the score for the mine. Scores for predicted groundwater impacts were often based on qualitative information or descriptions (e.g., "moderate" effects expected on groundwater quality). If an EIS entry noted anything regarding predicted groundwater quality that was negative, it was scored as a 2 (moderate impacts). Information on long-term groundwater quality impacts was also noted.

Table 5.19 lists the mines with predicted groundwater quality impacts that fell into in the four categories for predicted groundwater quality impacts.

No Information Available

No information was available on predicted groundwater quality impacts for 7 (10%) of the 71 NEPA mines. Two of the six mines had EAs rather than EISs (Royal Mountain King, CA (EIR-EA); Pete, NV). The Ray Mine in Arizona, which had a land-exchange EIS, acknowledged that mining will likely affect groundwater, but stated that a description of impacts was not possible because a detailed mine plan had not been developed. The East Boulder Mine in Montana predicted that nitrates from blasting agents and seepage from tailings impoundments could enter groundwater, but no estimates were made about potential impacts on groundwater. As noted in section 5.5, the Montana Tunnels Mine in Montana predicted that poor quality water would seep from the pit to groundwater in 480 years, but no estimates were made of the impact on groundwater.

Low Groundwater Quality Impacts

The majority of the mines (56 or 79%) predicted that groundwater quality impacts would be low and below relevant standards. A number of mines mentioned that there would be no impacts to groundwater outside of the mine area or of mixing zones, implying that groundwater on site would be impacted by the proposed actions. A number of the other mines stated that some combination of large depths to groundwater, the presence of neutralizing rock, and proposed mitigation measures would ensure that groundwater quality would not be impacted.

Moderate Groundwater Quality Impacts

Four mines (6%) predicted moderate groundwater quality impacts, exceeding water quality standards by up to 10 times, after mitigation were in place. Thompson Creek Mine in Idaho mentioned the potential for seepage from tailings impoundments and waste rock dumps to groundwater escaping the seepage control system, resulting in moderate groundwater impacts. The Tyrone Mine mentioned an existing groundwater plume from the stockpile and exceedence of the fluoride standard. The Cortez Pipeline Mine in Nevada predicted low groundwater quality impacts from proposed facilities but stated that the quality of reinfiltration of dewatering water may be degraded by soluble constituents in previously unsaturated alluvium. The Marigold Mine in Nevada predicted that escape of constituents from the heap leach pad could degrade groundwater quality.

Table 5.19. Predicted Groundwater Quality Impacts

0		1		2		3	
No information available		Low		Moderate		High	
AJ Project	AK	Fort Knox	AK	Thompson Creek*	ID	Pogo Project	AK
Red Dog	AK	Greens Creek*	AK	Tyrone Little Rock	NM	McLaughlin*	CA
Ray*	AZ	Kensington Project	AK	Cortez Pipeline	NV	Zortman and Landusky*	MT
Royal Mountain King*	CA	True North	AK	Marigold	NV	Golden Sunlight*	MT
East Boulder	MT	Bagdad*	AZ				
Montana Tunnels	MT	Carlotta	AZ				
Pete	NV	Cyprus Tohono	AZ				
		Morenci	AZ				
		Safford (Dos Pobres)	AZ				
		Sanchez	AZ				
		Yarnell	AZ				
		American Girl*	CA				
		Castle Mountain*	CA				
		Hayden Hill	CA				
		Imperial	CA				
		Jamestown*	CA				
		Mesquite	CA				
		Beartrack	ID				
		Black Pine	ID				
		Grouse Creek*	ID				
		Stibnite	ID				
		Stone Cabin	ID				
		Basin Creek	MT				
		Beal Mountain*	MT				
		Black Pine*	MT				
		Diamond Hill	MT				
		Mineral Hill*	MT				
		Montanore	MT				
		Rock Creek	MT				
		Stillwater*	MT				
		Troy	MT				
		Copper Flat	NM				
		Austin Gold Venture	NV				
		Bald Mountain	NV				
		Battle Mountain Phoenix	NV				
		Cortez	NV				
		Dash	NV				
		Florida Canyon	NV				

For predicted impacts (considering effects of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

Table 5.19. Predicted Groundwater Quality Impacts (continued)

0		1		2		3	
No information available		Low		Moderate		High	
		Gold Quarry	NV				
		Goldstrike	NV				
		Griffon	NV				
		Jerritt Canyon	NV				
		Leeville	NV				
		Lone Tree	NV				
		Mule Canyon	NV				
		Olinghouse	NV				
		Rain	NV				
		Robinson (Ruth)	NV				
		Rochester	NV				
		Round Mountain	NV				
		Ruby Hill	NV				
		Trenton Canyon	NV				
		Twin Creeks	NV				
		Gilt Edge	SD				
		Lisbon Valley	UT				
		Flambeau	WI				
	7		56		4		4

For predicted impacts (considering effects of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

High Groundwater Quality Impacts

Four of the 71 NEPA mines predicted high groundwater quality impacts after mitigation were considered. The Pogo Mine in Alaska predicted increases in arsenic (of up to 500 µg/l) and cyanide concentrations in alluvial groundwater from the underground mine, even after plugging and backfilling. The McLaughlin Mine in California predicted that seepage from the tailings facility would result in permanent degradation of local groundwater and noted the potential for shallow groundwater to flowing toward Hunting Creek. The McLaughlin EIS stated that the local groundwater was not connected to the regional system, so water supplies would not be impacted. A cyanide plume (from tailings seepage) already existed at the Golden Sunlight Mine in Montana when the 1997 EIS was written. The EIS stated that seepage from the tailings impoundment and one of the waste rock complexes would require perpetual treatment. The 2001 Zortman and Landusky Mines EIS predicted that concentrations of most contaminants from the Zortman and Landusky Mines would increase over time, and pit backfill would increase contaminant loads in the short term. The 1996 EIS predicted that acid and metal concentrations in toe seeps could increase or, at best, remain roughly unchanged for the first few years after capping.

Long-term Groundwater Quality Impacts

Several mines predicted groundwater impacts that would be long-term or that would not occur for years into the future. The Pogo Mine in Alaska predicted that increases in arsenic and total dissolved solids would occur from the underground mine over the long-term (hundreds to thousands of years), after plugging and backfilling after mine closure. The McLaughlin Mine in California predicted that the proposed tailings facility would allow 40 gpm of seepage into local groundwater, and this impact would be long term, resulting in permanent degradation of the local groundwater. The 1997 Golden Sunlight EIS predicted that seepage from Tailings Impoundment No.2 and West Waste Rock Complex would require perpetual treatment. At the Montana Tunnels Mine, as noted in Section 5.5, poor quality water was not expected to seep out of the pit and discharge to groundwater (at 15 gpm) until 480 years later when water levels in the pit reached equilibrium.

The 2001 Zortman and Landusky EIS predicted that backfilling would increase loads of contaminants in the short term, but that in the long term, removing waste rock would have a positive impact on groundwater quality. The Battle

Mountain Complex EIS noted that there was a potential for long-term impacts to groundwater quality during the post-closure period, but that with the contingent long-term groundwater management plan, significant impacts to groundwater were not expected.

5.8.2. PREDICTED SURFACE WATER IMPACTS

The EIS information on predicted surface water quality impacts was summarized and scored according to the following four categories:

- No information available (0)
- Low surface water quality impacts (< relevant standards) (1)
- Moderate surface water quality impacts (≥ and up to 10 times relevant standards) (2)
- High surface water quality impacts (>10 times standards) (3)

For mines with multiple EISs, the EIS with the highest individual score for predicted surface water impacts was used as the score for the mine. Scores for predicted surface water impacts were often based on qualitative information or descriptions (e.g., no impacts expected on surface water quality). If an EIS entry noted anything regarding predicted surface water quality that was negative, including sedimentation or erosion effects on surface water, it was scored as a 2 (moderate impacts). Information on long-term surface water quality impacts was also discussed.

Table 5.20 lists the mines with predicted surface water impacts in each of the four categories.

No Information Available

No information was available on predicted surface water quality impacts for six (8%) of the mines. Two of these mines (Royal Mountain King, CA; True North, AK) had EAs rather than EISs, and the Ray Mine in Arizona had a land-exchange EIS. The Diamond Hill Mine in Montana mentioned weathering of sulfides and the Dash Mine in Nevada mentioned soil loss, but neither contained specifics on surface water quality predictions. The Montana Tunnels Mine in Montana mentioned destruction of springs and decreased flows in streams, and as discussed in the surface water quality potential section. Poor-quality water was expected to seep out of the pit in 480 years, but the impact on surface water quality was not mentioned.

Low Surface Water Quality Impacts (water quality standards not exceeded)

The vast majority (57 or 80%) of the mines predicted that surface water quality impacts would be low or non-existent. As for predicted groundwater quality impacts, mines that predicted low surface water quality impacts mentioned the effects of mixing zones, implying that surface water would be impacted by the proposed actions but dilution would reduce concentrations to below standards. Other mines stated that some combination of distance to or low amount of surface water, low potential for acid drainage or contaminant leaching, and proposed mitigation or management measures would ensure that surface water quality would not be impacted.

Moderate Surface Water Quality Impacts (≥ and up to 10 times relevant standards)

Seven (10%) of the mines predicted that surface water quality impacts would be moderate, exceeding relevant standards by up to 10 times, where specific water quality conditions were mentioned. The Pogo Project EIS predicted moderate impacts to Liese Creek from tailings during mining operations. Modeling conducted for the McLaughlin Mine EIS in California predicted that arsenic, nickel, zinc, silver, iron and copper concentrations would not exceed drinking water standards in Hunting Creek but that manganese would slightly exceed its standard. The EIS for the Beartrack Mine in Idaho predicted exceedence of zinc standards in one reach of Napias Creek, and the Thompson Creek Mine in Idaho predicted exceedence of aquatic life criteria in Bruno Creek during low-flow conditions from tailings infiltration. The Olinghouse Mine in Nevada predicted reduction in discharge and sedimentation impacts to surface water.

Table 5.20. Predicted Surface Water Quality Impacts

0		1		2		3	
No information available		Low		Moderate		High	
True North	AK	AJ Project	AK	Pogo Project	AK	Zortman and Landusky*	MT
Ray*	AZ	Fort Knox	AK	McLaughlin*	CA		
Royal Mountain King*	CA	Greens Creek *	AK	Beartrack	ID		
Diamond Hill	MT	Kensington Project	AK	Thompson Creek*	ID		
Montana Tunnels	MT	Red Dog	AK	Tyrone Little Rock	NM		
Dash	NV	Bagdad*	AZ	Marigold	NV		
		Carlotta	AZ	Olinghouse	NV		
		Cyprus Tohono	AZ				
		Morenci	AZ				
		Safford (Dos Pobres)	AZ				
		Sanchez	AZ				
		Yarnell	AZ				
		American Girl*	CA				
		Castle Mountain*	CA				
		Hayden Hill	CA				
		Imperial	CA				
		Jamestown*	CA				
		Mesquite*	CA				
		Black Pine	ID				
		Grouse Creek*	ID				
		Stibnite	ID				
		Stone Cabin	ID				
		Basin Creek	MT				
		Beal Mountain*	MT				
		Black Pine*	MT				
		East Boulder	MT				
		Golden Sunlight*	MT				
		Mineral Hill*	MT				
		Montanore	MT				
		Rock Creek	MT				
		Stillwater*	MT				
		Troy	MT				
		Copper Flat	NM				
		Austin Gold Venture	NV				
		Bald Mountain	NV				
		Battle Mountain Phoenix	NV				
		Cortez	NV				
		Cortez Pipeline	NV				
		Florida Canyon*	NV				

For predicted impacts (considering effects of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

Table 5.20. Predicted Surface Water Quality Impacts (continued)

0		1		2		3	
No information available		Low		Moderate		High	
		Gold Quarry	NV				
		Goldstrike	NV				
		Griffon	NV				
		Jerritt Canyon*	NV				
		Leeville	NV				
		Lone Tree*	NV				
		Mule Canyon	NV				
		Pete	NV				
		Rain	NV				
		Robinson (Ruth)	NV				
		Rochester*	NV				
		Round Mountain*	NV				
		Ruby Hill*	NV				
		Trenton Canyon	NV				
		Twin Creeks*	NV				
		Gilt Edge	SD				
		Lisbon Valley	UT				
		Flambeau*	WI				
	6		57		7		1

For predicted impacts (considering effects of mitigation): Low = < water quality standards; Moderate = predicted to exceed water quality standards by 1 - 10 times; High = predicted to exceed water quality standards by > 10 times.

High Surface Water Quality Impacts

One mine (Zortman and Landusky, MT) predicted high surface water quality impacts as a result of mining, even after mitigation were considered. Some irreversible impacts to the surface water quality were expected from the leach pad and from other mine features such as waste rock and open pits even though current water quality was already poor.

Long-term Surface Water Quality Impacts

A number of mines mentioned the effect of time on predicted surface water quality impacts. The EIS for the Greens Creek Mine in Alaska predicted a lag time for acid generation in tailings of 20 to 50 years. The EIS for the Pogo Mine in Alaska predicted that after closure of the dry stack tailings, water quality would improve. Although surface water quality impacts were predicted to be low at the Grouse Creek Mine in Idaho, the EIS mentioned that if acid drainage occurs, the effects could be long-term. The Beal Mine in Montana was predicted to have both long and short-term environmental effects in German Gulch, but the effects were not predicted to be significant in terms of either areal extent or severity.

As mentioned above, poor-quality water was not expected to seep out of the pit at the Montana Tunnels Mine in Montana until pit water levels equilibrate in 480 years, but the impact on water quality in Spring Creek was unknown. Long-term surface water quality impacts were not expected at the Zortman and Landusky Mine in Montana because pad water at the bottom of one of the Landusky leach pads, although predicted to become acid over time, would be contained on a liner. Water quality impacts in the northern drainages were predicted to increase if acid-generating material was placed as pit backfill in the headwaters of these drainages. For a mine expansion proposal initially approved in 1996 at the Zortman Mine, improved water quality was predicted over time as a result of reduced constituent loads in Ruby and Carter Gulch due to removal of the Alder Gulch waste rock dump, the Ruby Gulch tailings, the proposed sorting of backfill, and effective reclamation of the Zortman pit complex. This Zortman mine expansion never occurred and was withdrawn by the operator subsequent to bankruptcy. Water quality impacts to surface water from sulfate were predicted to occur at the Golden Sunlight Mine in Montana but not for 500 years or more.

A number of mines mentioned the effect of time on predicted surface water quality impacts. The EIS for the Greens Creek Mine in Alaska predicted a lag time for acid generation in tailings of 20 to 50 years. The EIS for the Pogo, Alaska, Mine predicted that after closure of the dry stack tailings, water quality would improve. Although surface water quality impacts were predicted to be low at the Grouse Creek Mine in Idaho, the EIS mentioned that if acid drainage occurs, the effects could be long-term. The Beal Mine in Montana was predicted to have both long and short-term environmental effects in German Gulch, but the effects were not predicted to be significant in terms of either areal extent or severity. As mentioned above, poor-quality water was not expected to seep out of the pit at the Montana Tunnels Mine until pit water levels equilibrate in 480 years, but the impact on water quality in Spring Creek was unknown.

5.8.3. PREDICTED PIT WATER IMPACTS

The information on predicted pit water quality impacts was summarized and scored according to the following five categories:

- No information available (0)
- Low pit water quality impacts (concentrations less than relevant standards or water quality similar to surrounding groundwater) (1)
- Moderate pit water quality impacts (≥ and up to 10 times relevant standards) (2)
- High pit water quality impacts (>10 time relevant standards) (3)
- No pit lake or long-term standing water expected (underground mine or pit above the water table) (4)

For mines with multiple EISs, the EIS with the highest individual score (1, 2, or 3) for predicted pit water impacts were used as the score for the mine. Scores for predicted pit water impacts were often based on qualitative information or descriptions (e.g., pit water quality expected to be poor). If an EIS entry noted anything regarding predicted pit water quality that was negative, it was scored as a 2 (moderate impacts). If the pit was proposed to be backfilled but the EIS did not address backfill water quality, it was scored as a 0. For mines with multiple proposed pits, the pit with the highest score (1, 2, 3, or 4) was used to score the mine as a whole. Information on long-term pit water quality impacts and the need for perpetual treatment are also discussed.

Table 5.21 lists the mines with predicted pit water quality impacts in each of the five categories.

No Information Available

Twelve (17%) of the mines provided no information on predicted pit water quality. Four of the mines (True North, AK; Royal Mountain King, CA (EIR-EA); Black Pine, ID; Austin Gold Venture, NV) had EAs rather than EISs, and the Morenci and Ray mines in Arizona had land-exchange EISs.

Low Pit Water Quality Impacts

EISs for 12 (17%) of the mines predicted pit water quality would be acceptable for all potential uses, either by being below water quality standards or having a composition similar to surrounding groundwater. Of these, only one (Safford, AZ) conducted pit lake water quality modeling. The Safford Project had high potential (pre-mitigation) pit water quality impacts. The designation as high related predominantly to poor water quality in an existing pit lake.

Two other mines (Grouse Creek and Thompson Creek, ID) had moderate potential pit water quality impacts, and the others in this category all had low potential pit water quality impacts. The main reason given for predicting low pit water quality impacts was the presence of low acid drainage and/or contaminant leaching potential in the pit rather than improvements from any mitigation measures. However, the Lisbon Valley Mine in Utah predicted high potential (pre-mitigation) pit water quality impacts, but dilution from diverted surface runoff was predicted to improve water quality to better than existing groundwater conditions.

Table 5.21. Predicted Pit Water Quality

0		1		2		3		4	
No information available		Low		Moderate		High		No pit lake expected to form (pit above water table or no pit)	
True North	AK	Fort Knox	AK	Sanchez	AZ	McLaughlin*	CA	AJ Project	AK
Red Dog	AK	Safford (Dos Pobres)	AZ	Jamestown*	CA	Golden Sunlight	MT	Greens Creek *	AK
Bagdad*	AZ	Yarnell	AZ	Mesquite*	CA	Montana Tunnels	MT	Kensington Project	AK
Carlotta	AZ	Castle Mountain*	CA	Beartrack	ID	Zortman Landusky*	MT	Pogo Project	AK
Morenci	AZ	Imperial	CA	Copper Flat	NM	Gold Quarry	NV	Cyprus Tohono	AZ
Ray*	AZ	Grouse Creek*	ID	Tyrone Little Rock	NM	Lone Tree*	NV	American Girl*	CA
Royal Mountain King*	CA	Stibnite	ID	Bald Mountain	NV	Twin Creeks*	NV	Hayden Hill	CA
Black Pine	ID	Thompson Creek*	ID	Battle Mountain Phoenix	NV	Gilt Edge	SD	Black Pine*	MT
Stone Cabin	ID	Basin Creek	MT	Cortez Pipeline	NV	Flambeau*	WI	Diamond Hill	MT
Austin Gold Venture	NV	Beal Mountain*	MT	Goldstrike	NV			East Boulder	MT
Dash	NV	Pete	NV	Marigold	NV			Mineral Hill*	MT
Florida Canyon*	NV	Lisbon Valley	UT	Olinghouse	NV			Montanore	MT
				Mule Canyon	NV			Rock Creek	MT
				Robinson (Ruth)	NV			Stillwater*	MT
				Round Mountain*	NV			Troy	MT
								Cortez	NV
								Griffon	NV
								Jerritt Canyon*	NV
								Leeville	NV
								Rain	NV
								Rochester*	NV
								Ruby Hill*	NV
								Trenton Canyon	NV
	12		12		15		9		23

Moderate Pit Water Quality Impacts

Moderate pit water quality impacts were predicted for 15 (21%) of the mines. A number of the mines in this category mentioned the effect of evapoconcentration on pit water quality. Six of the mines in this category conducted pit lake modeling to estimate pit water quality (Mesquite, CA; Cortez Pipeline, Goldstrike, Olinghouse, Robinson (Ruth) and Round Mountain, NV). The Robinson (Ruth), Nevada, EIS mentioned some improvements in water quality resulting from removal of mineralization from mining of the pit.

High Pit Water Quality Impacts

High pit water quality impacts were predicted at nine (13%) of the mines. Five mines in this category modeled pit lake or pit backfill leachate water quality (Gold Quarry, Lone Tree and Twin Creeks, NV; Gilt Edge, SD; Flambeau, WI). The McLaughlin Mine in California expected pit water with high concentrations of metals, even though neutralizing material was present in the pit. The Golden Sunlight Mine in Montana noted the need for perpetual treatment of pit water. The Zortman and Landusky Mine in Montana predicted that backfilling the pit would increase concentrations, at least initially, but that sulfide oxidation could be slowed by backfilling. Pit water quality at the Gold Quarry Mine in Nevada was predicted to exceed concentrations of metals by over 10 times but ultimately to be similar to surrounding groundwater quality. As discussed below, a number of the mines that used modeling to predict pit water quality predicted changing water quality over time in the pit lake or backfill. At the Twin Creeks Mine in Nevada, hydrogeochemical pit lake modeling predicted that antimony, arsenic and thallium would exceed drinking water standards (antimony and arsenic by over 10 times) for the life of the pit but that aluminum concentrations would only be exceeded for the first 27 years until the lobes of the pit lakes merged. The model also predicted that there would be no net outflow to groundwater or surface water.

No Pit Lake or Long-Term Standing Water Expected

Almost one-third (23 or 32%) of the mines predicted that pit water (either in a pit lake or in backfill) would not be present, either because it was an underground mine or because the bottom of the pit would be above the water table. The following mines in this category are all expected to have open pits or backfilled open pits, but the bottom of the pits are predicted to be above the water table: Cyprus Tohono, Arizona; American Girl and Hayden Hill, California; and all the Nevada mines except Leeville, which is an underground mine. The remainder of the mines listed in this category in Table 5.21, including the Leeville Mine in Nevada, are underground mines.

Long-term Pit Water Quality Impacts in Long-Term

A number of mines predicted that pit water quality impacts would occur in the long-term or change over time. A number of the mines that used hydrogeochemical models to predict pit water quality reported predicted changes in water quality over time. For example, in Nevada, the Cortez Pipeline Mine predicted good pit water quality initially, with drinking water standards not exceeded until ~190 years after the end of mining and migration of pit waters into adjacent aquifers more than 250 years after end of mining. Also in Nevada, the Goldstrike Mine pit water was predicted to exceed, in the long term, the drinking water standard for arsenic, cadmium, fluoride, iron, lead, and TDS. Similarly, at the Lone Tree Mine in Nevada, pit lake water quality was predicted to be acidic initially but become neutral after 10 years, exceeding drinking water standards for arsenic and sulfate before it becomes neutral. Cadmium would exceed drinking water standards for only one year, and for nickel, fluoride and antimony exceedence would happen only after 25 years. At the Twin Creeks Mine in Nevada, hydrogeochemical pit lake modeling predicted that antimony, arsenic, and thallium would exceed drinking water standards (antimony and arsenic by over ten times) for the life of the pit but that aluminum concentrations would only be exceeded for the first 27 years until the lobes of the pit lakes merged. The model also predicted that there would be no net outflow to groundwater or surface water. Long-term pit water quality was predicted by modeling to be poor at the Gilt Edge Mine in South Dakota. Zinc and arsenic concentrations were predicted to increase to 8.5 and 1.05 mg/l respectively, by year five after pit closure, and copper concentrations were expected to increase to 0.4 by year 34.

Perpetual Treatment Required

Mines in Montana made long-term pit water quality predictions without modeling, with the Golden Sunlight Mine predicting that water entering or in the pit would require perpetual treatment. The Montana Tunnels, Montana, Mine pit water was predicted to be initially acidic with elevated concentrations of heavy metals, but as the pit continued to fill with water, pyrite oxidation rates were expected to diminish with burial of the diatreme. Finally, at the Zortman and Landusky Mine, pit backfilling was expected to increase loads of contaminants in the short term due to the disturbance of acid generating material, the re-establishment of flowpaths and mobilization of soluble oxidation products.

Proposed Action Would Improve Pit Water Quality

The Lisbon Valley Mine in Utah predicted high potential (pre-mitigation) pit water quality impacts, but dilution from diverted surface runoff was predicted to improve water quality to better than the existing groundwater conditions.

One mine, (Robinson (Ruth), NV) predicted improvement of pit water quality as a result of the proposed actions. Some improvement in pit (Liberty and Ruth pits) water was expected as mineralization is removed by mining. Further, to the extent that acidic solutions were discharged into the pit during historic leaching activities, pit dewatering and subsequent refilling will also result in improved water quality.

5.9. DISCHARGE INFORMATION

In many cases, EISs identified mines or certain facilities at mines (e.g., heap leach pads or tailings impoundments) as "zero discharge" facilities. There is some debate about the meaning of "zero discharge," because discharges can occur as spills or leaks from liners, despite design requirements. For the purposes of this analysis, a "zero discharge" facility is defined by the design goal rather than the actual performance.

Many mines also have discharges to surface water that are regulated by either federal National Pollution Discharge Elimination System (NPDES) permits or similar permits issued by individual states under EPA authority. EPA classifies larger, more regulated facilities as "major" facilities and smaller facilities as "minor" facilities. These discharges can be treated or untreated, depending on the concentrations in the discharge water.

A smaller number of mines discharge to groundwater, typically through re-infiltration basins, which is a form of land application. Often the water discharged to groundwater is mine or pit dewatering water. Land application or infiltration basins are considered a form of treatment, so technically, all water discharged to groundwater using these methods is treated. It is also possible to re-inject mine water to groundwater through deep wells. However, no mines reviewed used this type of groundwater discharge.

Table 5.22 lists the mines described in EISs as zero discharge facilities and those that propose to discharge to surface water and groundwater. Note that the total number of mines does not add to 71 because a number of the mines do not have surface water or groundwater discharges and are also not zero-discharge facilities.

Zero Discharge Facilities

Twenty-eight (39%) of the mines had proposed zero-discharge designs for at least some of their facilities. Tailings, heap leach, open pits, mills and dams were described as being zero-discharge facilities. Open pits were described as being "zero discharge" facilities if they did not discharge to groundwater and instead acted as a groundwater sink. Using these definitions, mines with individual "zero discharge" facilities could still require a NPDES permit.

Table 5.22. Discharge Information

1		2		3	
Zero Discharge Facility		Discharge to Surface Water		Discharge to Groundwater	
AJ Project	AK	AJ Project	AK	Stillwater*	MT
Fort Knox	AK	Greens Creek*	AK	Cortez Pipeline	NV
Cyprus Tohono	AZ	Kensington Project	AK	Leeville	NV
Morenci	AZ	Pogo Project	AK	Twin Creeks*	NV
Safford (Dos Pobres)	AZ	Red Dog	AK		
American Girl*	CA	Bagdad*	AZ		
Castle Mountain*	CA	Carlotta	AZ		
Hayden Hill	CA	Morenci	AZ		
Jamestown*	CA	Ray*	AZ		
Grouse Creek*	ID	Safford (Dos Pobres)	AZ		
Stibnite	ID	McLaughlin*	CA		
Thompson Creek*	ID	Beartrack	ID		
Beal Mountain*	MT	Thompson Creek*	ID		
Black Pine*	MT	Basin Creek	MT		
Mineral Hill*	MT	Beal Mountain*	MT		
Stillwater*	MT	East Boulder	MT		
Austin Gold Venture	NV	Mineral Hill*	MT		
Battle Mountain Phoenix	NV	Montana Tunnels	MT		
Cortez	NV	Montanore	MT		
Cortez Pipeline	NV	Rock Creek	MT		
Florida Canyon*	NV	Stillwater*	MT		
Griffon	NV	Zortman and Landusky*	MT		
Marigold	NV	Gold Quarry	NV		
Mule Canyon	NV	Goldstrike	NV		
Robinson (Ruth)	NV	Lone Tree*	NV		
Round Mountain*	NV	Twin Creeks*	NV		
Ruby Hill*	NV	Gilt Edge	SD		
Twin Creeks*	NV	Flambeau*	WI		
	28		28		4

Surface Water Discharges

Twenty-eight (39%) of the mines proposed discharging to surface water, and all but one of these (Leeville, NV) had NPDES permits. Of the 28 mines with NPDES permits, ten are major and 13 are minor facilities. For the Leeville Mine, dewatering water was proposed to be disposed of in re-infiltration basins, but if that does not provide sufficient volume, the EIS stated that the dewatering water could be discharged to the Humboldt River. It is notable that eight mines described as zero discharge facilities (AJ, AK; Morenci and Stafford, AZ; Thompson Creek, ID; Beal Mountain, Mineral Hill, and Stillwater, MT; Twin Creeks, NV) also have NPDES permits. In those cases, particular facilities may be identified as "zero discharge" (e.g., heap leach or tailings facility), and/or the NPDES permits are for stormwater and pit dewatering and are not related to the discharge of pollutants.

Groundwater Discharges

Four mines (Stillwater, MT; Cortez Pipeline, Leeville, and Twin Creeks, NV) proposed to discharge to groundwater. At the Stillwater Mine, adit water was proposed to be land applied. At the three Nevada mines, dewatering water was proposed to be discharged to groundwater through re-infiltration basins.

5.10. GENERAL RELATIONSHIPS AMONG ENVIRONMENTAL CHARACTERISTICS IN THE NEPA DOCUMENTS

Sections 5.2 to 5.9 presented the general findings on information in the EISs for the 71 NEPA mines reviewed in detail. In this Section, the relationships among environmental characteristics identified in the NEPA documents for these mines are examined. These characteristics include:

- geology and mineralization
- acid drainage potential
- contaminant leaching potential
- climate
- proximity to water resources

This section examines, for example, if there is a relationship between geology and mineralization and identified acid drainage potential, or between climate and identified proximity to water resources. The study also examines whether there is a relationship between factors such as acid drainage potential and the identified potential for water quality impacts. In theory, there should be a relationship between mineralogy and acid drainage potential, between climate and depth to groundwater, and among these factors and the likelihood that water resources will be impacted.

5.10.1. GEOCHEMICAL CHARACTERISTICS: GEOLOGY/MINERALIZATION, ACID DRAINAGE POTENTIAL, AND CONTAMINANT LEACHING POTENTIAL

In a number of cases, little information was available in the EISs on rock type or mineralization. Geologic and mineralogic information available in the EISs was generally insufficient to make even general predictions about contaminant leaching potential based on mineralogy (e.g., identification of arsenic-containing minerals).

Some of the more notable mines, for which no or insufficient information was available in the NEPA documents, are listed below.

- The Pogo Project in Alaska, which EIS otherwise might be considered one of the more complete and comprehensive from a water quality predictions standpoint.
- Jamestown, McLaughlin and Royal Mountain King mines in California, had EISs that were conducted as part of California's EIR process and have subsequently resulted in contaminant leaching that could have been identified mineralogically.
- The Austin Gold Venture and Rain mines in Nevada where new project permitting was conducted using EAs and contaminant leaching has occurred that could have been predicted from knowing the mineralogy.

In many cases, mines identified with low-sulfide content may be based on insufficient characterization applied to the EIS. For example, Jerritt Canyon's EIS indicates low sulfide content, but the fact that the ore requires roasting before leaching indicates that relatively high sulfide and/or carbon content is present in the ore. Six mines had no information on acid drainage potential, and 15 mines had no information on contaminant leaching potential.

The identification of geology and mineralization, as currently conducted in EISs, is generally a blunt tool for predicting water quality impacts. Geologic and mineralogic information is usually focused on the ore body rather than on all mined materials that could potentially impact water resources. There were relatively weak relationships between geology, mineralization or ore association and acid drainage potential. Mineralization scores that favored acid drainage development (three to five: moderate to high sulfide contents with or without neutralizing material) generally had higher scores for acid drainage potential. However, 50% (nine of 18) of mines that had mineralization/ore associations of four (sulfides present, no associated carbonates) and five (high sulfide content, carbonates low/not present) reported low acid drainage potential. The reasons for the low acid drainage potential scores may be related to different rocks being evaluated for mineralization and acid drainage potential or to other factors that were considered by the mine in determining the potential for acid drainage. However, the discrepancy or lack of good agreement between identified mineralization and acid drainage potential highlights the importance of coordinating mineralogic and acid drainage potential evaluations in the NEPA process. As noted in the companion report (Maest et al., 2005), the same geochemical test units should be used for testing of all parameters used to predict water quality impacts. In addition, more extensive information on mineralogy and mineralization should be included in EISs. Similarly, there was a weak relationship between mineralization and contaminant leaching potential. Of the 18 mines that identified moderate to high sulfides present and little neutralization potential, seven (39%) identified low contaminant leaching potential. In general, rocks with higher sulfide content are expected to leach higher concentrations of contaminants, especially heavy metals.

Although the relationship between acid drainage potential and contaminant leaching potential is not necessarily good, wastes that develop acid drainage usually have high concentrations of other contaminants as well, especially heavy metals. Only four mines identified a high acid drainage potential (Black Pine, Golden Sunlight, and Zortman and Landusky, MT; Battle Mountain Complex, NV). None of these four mines identified a low contaminant leaching potential. However, of the 19 mines that identified a moderate acid drainage potential, seven (37%) identified a low contaminant leaching potential. Twelve mines identified a high contaminant leaching potential. It is possible to have a high contaminant leaching potential and a low acid drainage potential, because acidic conditions are not a requirement for contaminant leaching. Only two mines identified high acid drainage and contaminant leaching potential: Golden Sunlight in Montana, and the Battle Mountain Complex in Nevada. Zortman and Landusky identified both high acid drainage and contaminant leaching potential, but not until the fourth EIS/EA in 2001.

Fourteen mines identified both moderate to high acid drainage and contaminant leaching potential. In theory, these mines should also identify a higher potential for water quality impacts (recall that "potential" refers to pre-mitigation conditions). Ten of these 14 mines (71%) also identified a moderate to high potential for surface water and groundwater quality impacts. However, only one of the 14 mines predicted moderate or high surface water quality impacts post-mitigation (Zortman and Landusky, MT). Only two of the 14 identified moderate or high groundwater quality impacts (Zortman and Landusky and Golden Sunlight, MT). Therefore, even though a high proportion of the mines link geochemical characteristics to water quality, the vast majority declare in EISs that mitigation measures will prevent water quality impacts.

5.10.2. HYDROLOGIC AND CLIMATIC CHARACTERISTICS

Relationship between Proximity to Surface Water and Depth to Groundwater

Based on the data in Section 5.4, hydrology, the surface water and groundwater classifications are compared in Table 5.23. The data indicate that extreme differences in proximity to groundwater and surface water rarely exist. Mines with deep groundwater generally also are located far from surface water resources, and mines with shallow groundwater also are located close to surface water resources. However, some variability within the various classifications does exist (e.g., springs may exist in desert areas with no perennial streams, and deep groundwater may still result in discharges directly to surface water – typically from mine dewatering).

Table 5.23. Comparison of Surface Water and Groundwater Hydrology Classifications for the 71 NEPA Mines Reviewed in Detail

		Groundwater Hydrology Classification							
		No information provided		Depth to groundwater > 200 ft		Depth to groundwater < 200 ft but > 50 ft		Depth to groundwater 0-50 ft and/or springs on site	
Surface Water Hydrology Classification	No information provided	Imperial	CA	Rain	NV			Yarnell	AZ
		Royal Mountain King	CA					Diamond Hill	MT
	Intermittent/ephemeral streams on site-perennial streams > 1 mile away	Copper Flat	NM	Castle Mountain	CA	Cyprus Tohono	AZ	Bagdad	AZ
				Bald Mountain	NV	Mesquite	CA	Safford (Dos Pobres)	AZ
				Cortez Pipeline	NV	Black Pine	ID	Sanchez	AZ
				Griffon	NV	Lisbon Valley	UT	American Girl	CA
				Olinghouse	NV			Cortez	NV
								Florida Canyon	NV
								Gold Quarry	NV
								Lone Tree	NV
	Intermittent/ ephemeral streams on site - perennial streams <1 mile away	True North	AK	Leeville	NV	Marigold	NV	McLaughlin	CA
		Austin Gold Venture	NV	Ruby Hill	NV	Pete	NV	Golden Sunlight	MT
						Round Mountain	NV	Montana Tunnels	MT
								Stillwater	MT
								Battle Mountain Phoenix	NV
								Goldstrike	NV
								Robinson (Ruth)	NV
								Rochester	NV
								Flambeau	WI
	Perennial streams on site	AJ Project	AK	Ray	AZ	Mineral Hill	MT	Fort Knox	AK
		Carlotta	AZ	Montanore	MT	Twin Creeks	NV	Greens Creek	AK
		Tyrone Little Rock	NM	Trenton Canyon	NV			Kensington Project	AK
								Pogo Project	AK
								Morenci	AZ
								Hayden Hill	CA
								Jamestown	CA
								Beartrack	ID
								Grouse Creek	ID
								Stibnite	ID
								Stone Cabin	ID
								Thompson Creek	ID
								Basin Creek	MT
								Beal Mountain	MT
								Black Pine	MT
								East Boulder	MT
								Rock Creek	MT
								Troy	MT
								Zortman and Landusky	MT
								Dash	NV
								Jerritt Canyon	NV
								Gilt Edge	SD

5.10.3. COMBINATIONS OF GEOCHEMICAL AND HYDROLOGIC CHARACTERISTICS AND RELATIONSHIP TO POTENTIAL AND PREDICTED WATER QUALITY IMPACTS

Seventeen of the 71 NEPA mines reviewed identified moderate to high acid drainage potential and close proximity to surface water (perennial streams on site and/or direct discharges to surface water). Of these, 13 (77%) identified a moderate to high potential for surface water quality impacts. However, only two (12%) of these (Thompson Creek, ID and Zortman Landusky, MT) identified a high post-mitigation potential for surface water quality impacts (Table 5.24).

Table 5.24. Potential and Predicted Surface Water Quality Impacts for Mines with Moderate to High Acid Generation Potential and Close Proximity to Surface Water.

Name	State	Surface Water Impact Potential	Predicted Surface Water Quality Impacts
Greens Creek	AK	2	1
Carlotta	AZ	2	1
Hayden Hill	CA	2	1
Grouse Creek	ID	2	1
Stone Cabin	ID	1	1
Thompson Creek	ID	2	2
Beal Mountain	MT	2	1
Black Pine	MT	0	1
Montana Tunnels	MT	2	0
Montanore	MT	0	1
Zortman and Landusky	MT	3	3
Gold Quarry/Maggie Creek	NV	1	1
Goldstrike	NV	2	1
Jerritt Canyon	NV	2	1
Leeville	NV	2	1
Lone Tree	NV	2	1
Twin Creeks	NV	3	1

0 = no information; 1 = low; 2 = moderate; 3 = high.

Twenty of the 71 NEPA mines identified moderate to high acid drainage potential and close proximity to groundwater resources (0 – 50 ft depth to groundwater, springs on site, or discharges to groundwater). Of these, 15 (75%) identified a moderate to high potential for groundwater quality impacts. However, only three (15%) of these (Thompson Creek, ID; Golden Sunlight and Zortman and Landusky, MT) identified a high post-mitigation potential for groundwater quality impacts as shown in Table 5.25.

Similar results were found for the combination of contaminant leaching potential and proximity to water resources. Of the 17 mines with moderate to high contaminant leaching potential and close proximity to surface water resources, nine identified a moderate to high potential (pre-mitigation) for surface water quality impacts, but only two predicted moderate (Bear Track, ID) or high (Zortman and Landusky, MT) impacts to surface water after mitigation were in place, as shown in Table 5.26. Table 5.27 shows that 21 mines identified a moderate to high contaminant leaching potential and close proximity to groundwater resources. Of these 21 mines, 15 identified a moderate to high potential for groundwater quality impacts based on inherent characteristics. However, only four mines predicted that there would be moderate to high groundwater quality impacts after mitigation were in place.

Table 5.25. Potential and Predicted Groundwater Quality Impacts for Mines with Moderate to High Acid Drainage Potential and Close Proximity to Groundwater Resources

Name	State	Groundwater Impact Potential	Predicted Groundwater Impact
Greens Creek	AK	Low	Low
Hayden Hill	CA	Low	Low
Grouse Creek	ID	Low	Low
Stone Cabin	ID	No Info	Low
Thompson Creek	ID	Low	Moderate
Beal Mountain	MT	Low	Low
Black Pine	MT	Moderate	Low
Diamond Hill	MT	Low	Low
Golden Sunlight	MT	High	High
Montana Tunnels	MT	No Info	No Info
Zortman and Landusky	MT	Moderate	High
Battle Mountain Complex	NV	High	Low
Gold Quarry/ Maggie Creek	NV	High	Low
Goldstrike	NV	Moderate	Low
Jerritt Canyon	NV	Moderate	Low
Leeville	NV	High	Low
Lone Tree	NV	High	Low
Robinson (Ruth)	NV	Low	Low
Rochester	NV	Moderate	Low
Twin Creeks	NV	High	Low

These results suggest that even though a high proportion of the mines link a higher acid drainage or contaminant potential and close proximity to water with potential adverse impacts to water quality, the vast majority declare in EISs that mitigation measures will prevent these potential water quality impacts. Predictions of water quality not only do not assume "worst-case" conditions, they consistently assume "best-case" conditions, with all mitigation measures working effectively. Generally, post-mitigation predictions are more qualitative than pre-mitigation predictions (e.g., liners will not leak). As noted in Section 5, for mines with multiple EISs, the score represents the highest acid drainage potential, contaminant leaching potential and highest potential and predicted water quality. If individual EISs were examined, even fewer mines declared that inherent geochemical and hydrologic characteristics could adversely impact water quality.

Table 5.26. Potential and Predicted Surface Water Quality Impacts for Mines with Moderate to High Contaminant Leaching Potential and Close Proximity to Surface Water Resources

Name	State	Surface Water Impact Potential	Predicted Surface Water Impact Potential
Kensington Project	AK	Low	Low
Pogo Project	AK	Low	Moderate
Carlotta	AZ	Moderate	Low
Beartrack	ID	No Info	Moderate
Black Pine	MT	No Info	Low
Mineral Hill	MT	Low	Low
Montanore	MT	No Info	Low
Rock Creek	MT	Moderate	Low
Troy	MT	Low	Low
Zortman and Landusky	MT	High	High
Gold Quarry/ Maggie Creek	NV	Low	Low
Goldstrike	NV	Moderate	Low
Jerritt Canyon	NV	Moderate	Low
Leeville	NV	Moderate	Low
Lone Tree	NV	Moderate	Low
Twin Creeks	NV	High	Low
Gilt Edge	SD	Moderate	Low

5.10.4. CONCLUSIONS

The identification of geology and mineralization, as currently conducted in EISs, is generally a blunt tool for predicting water quality impacts. Geologic and mineralogic information is usually focused on the ore body rather than on all mined materials that could potentially impact water resources. Relatively weak relationships existed between geology and mineralization or ore association. Similarly, a relatively weak relationship existed between geology and mineralization and the potential for water quality impacts. The discrepancy or lack of good agreement between identified mineralization and acid drainage potential highlights the importance of coordinating mineralogic and acid drainage potential evaluations in the NEPA process. As noted in the companion report (Maest et al., 2005), the same geochemical test units should be used for testing of all parameters used to predict water quality impacts. In addition, more extensive information on mineralogy and mineralization should be included in EISs.

The EISs reviewed in detail spanned a period from 1978 to 2004. The availability of geochemical characterization data affects the ability to determine the potential for mines to release contaminants to water resources. Starting in 1980, regulatory agencies began to require or collect basic information on geochemical characterization, such as static and short-term leach testing. After 1990, many of the mines were conducting combinations of kinetic testing and static or short-term leach testing. EISs performed after about 1990 should have more reliable information on water quality impact potential than those with EISs completed before this time.

Table 5.27. Potential and Predicted Groundwater Quality Impacts for Mines with Moderate to High Contaminant Leaching Potential and Close Proximity to Groundwater Resources

Name	State	Groundwater Impact Potential	Predicted Groundwater Impact Potential
Kensington Project	AK	1	1
Pogo Project	AK	3	3
McLaughlin	CA	3	3
Beartrack	ID	0	1
Black Pine	MT	0	1
Golden Sunlight	MT	3	3
Rock Creek	MT	2	1
Stillwater	MT	1	1
Troy	MT	2	1
Zortman and Landusky	MT	2	3
Battle Mountain Complex	NV	2	1
Florida Canyon	NV	3	1
Gold Quarry/ Maggie Creek	NV	1	1
Goldstrike	NV	2	1
Jerritt Canyon	NV	2	1
Leeville	NV	2	1
Lone Tree	NV	1	1
Rochester	NV	2	1
Twin Creeks	NV	2	1
Gilt Edge	SD	2	1
Flambeau	WI	2	1

0 = no information; 1 = low; 2 = moderate; 3 = high.

6. WATER QUALITY PREDICTIONS AND IMPACTS AT NEPA MINES

This section contains a comparison of NEPA document identified potentials, mitigation, and predictions with actual water quality information contained either in subsequent NEPA documents or in other verifiable sources for selected mines.

Each case study includes a brief description of the information contained in the NEPA documents for each mine, along with information on water quality impacts either included in the NEPA documents, or contained in other documents as referenced. A summary of information on the water quality impacts and their causes is then provided for each mine. Additional information including the actual information from the NEPA document or other sources of information is contained in Appendix B Case Study Detailed Information (available at www/kuipersassoc.com or http://www.mineralpolicy.org/publications_welcome.cfm)

6.1. METHODS AND APPROACH

Two levels of study were undertaken for this project. The first level consisted of reviewing all available EISs for information relevant to water quality predictions in Section 5. The second level of study contained in this section, consisted of selecting a more limited number of mines for an in-depth study of predicted and actual water quality. The primary goal of the in-depth studies is to gain insights into the methods and approaches used to predict water quality and to determine whether these tools were successful.

The availability of water quality information after mining began was the primary factor in selecting a mine for in-depth study. For example, a number of operating or recently closed open-pit mines in Nevada and other states have no or very limited information on pit water quality because the mines have not stopped dewatering operations. These mines may have water quality information on groundwater or leachates, but no information is currently available that can be used to compare water quality predicted in the EIS to actual water quality. In addition to the availability of water quality information, the selected mines are also intended to represent a cross-section of commodities, mining types and climates.

In making the final selection of mines for in-depth study, the following priorities were identified:

- mines with long histories and NEPA documentation from new project to reclamation and closure;
- mines with different proximities to water resources but indicating water quality impacts
- mines that conducted some geochemical testing, and if possible, some water quality modeling;
- mines with different potentials to generate acid and leach contaminants to water resources

The list of mines that actually meet these criteria, particularly with respect to adequate reliable evaluations that have addressed water quality predictions and impacts, and are publicly available, is limited. NEPA histories at mines where subsequent EISs have been performed sometimes perform an evaluation of, current conditions and pre-mining predictions. These cases provide the most readily accessible, although not singular, opportunities for insight into the accuracy of water quality predictions as based on the information contained in NEPA documents.

A preliminary evaluation of the availability of operational water quality information was performed before selection of the case study mines. Operational and post-operational water quality information was available from EISs conducted after the new project EIS, especially for the states of Alaska, Montana, and Idaho, where multiple EISs were often available. In other states, such as Arizona, California, Nevada and Wisconsin, technical reports and water quality data were available from state agencies that regulate mining activities.

In addition to NEPA documents, which also include post-mining Engineering Evaluation/Cost Analysis (EE/CA), documents containing additional water quality information from some mines (e.g., Beal Mountain, MT; Grouse Creek, ID), water quality data were obtained for mines in Arizona, Nevada, California, and Wisconsin where situations with multiple EISs did not exist or those EISs did not address water quality impacts. The data for mines was obtained from files at the state regulatory agencies or from reports written by agency personnel or mining company consultants. In many cases the information obtained is useful for pointing out what information was not contained in original NEPA documents relevant to eventual water quality impacts. The authors recognize that additional insights might have been gained by analyzing additional water quality data for the various mine sites, however the focus was on obtaining data that was verifiable and/or otherwise contained in prepared reports as a matter of efficiency.

The information gathered is presented in the form of case studies, which consist of three sections: summary of water quality predictions from NEPA documents; actual water quality data from NEPA documents, state water quality databases and other sources; and a comparison of predicted and actual water quality.

6.2. GENERAL AND ENVIRONMENTAL CHARACTERISTICS OF CASE STUDY MINES

In all, 25 different mines with complete NEPA documents and additional information obtained are presented and examined in detail with respect to water quality predictions and impacts in this section. Table 6.1 shows the complete list of 25 mines selected for case studies.

Table 6.1 Case Study Mines

Name	State
Greens Creek	AK
Bagdad	AZ
Ray	AZ
American Girl	CA
Castle Mountain	CA
Jamestown	CA
McLaughlin	CA
Mesquite	CA
Royal Mountain King	CA
Grouse Creek	ID
Thompson Creek	ID
Beal Mountain	MT
Black Pine	MT
Golden Sunlight	MT
Mineral Hill	MT
Stillwater	MT
Zortman and Landusky	MT
Florida Canyon	NV
Jerritt Canyon	NV
Lone Tree	NV
Rochester	NV
Round Mountain	NV
Ruby Hill	NV
Twin Creeks	NV
Flambeau	WI

6.2.1. GENERAL CHARACTERISTICS OF CASE STUDY MINES

Table 6.2 shows the 25 mines selected for in-depth study and the variability in their locations, commodities, mine operation types, climatic characteristics and proximity to water resources.

Table 6.2 Mines Selected for In-Depth Study: General Mine Site Characteristics

Mine	State	Commodity	Mine Type	Climate	Proximity to Groundwater	Proximity to Surface Water
Greens Creek	AK	Au, Ag, Pb, Zn	UG, FG	Marine West Coast	0-50 ft. or springs	Perennial streams on site
Bagdad	AZ	Cu, Mo	OP, FG, DL-SX	Dry/Arid	0-50 ft. or springs	Perennial streams >1 mi. away
Ray	AZ	Ag, Cu	OP, FG, DL-SX	Dry/Arid	>200 ft.	Perennial streams on site
American Girl	CA	Au, Ag	OP, HL, VL	Dry/Arid	0-50 ft. or springs	Perennial streams >1 mi. away
Castle Mountain	CA	Au, Ag	OP, HL, VL	Dry/Arid	>200 ft.	Perennial streams >1 mi. away
Jamestown	CA	Au	OP, VL	Humid Tropical	0-50 ft. or springs	Perennial streams on site
McLaughlin	CA	Au	OP, VL	Humid Tropical	0-50 ft. or springs	Perennial streams >1 mi. away
Mesquite	CA	Au, Ag	OP, HL, VL	Dry/Arid	<200 ft. but >50 ft	Perennial streams >1 mi. away
Royal Mountain King	CA	Au, Ag	OP, FG, VL	Humid Tropical	No info	No info
Grouse Creek	ID	Au, Ag	OP, HL, VL	Boreal Forest	0-50 ft. or springs	Perennial streams on site
Thompson Creek	ID	Mo	OP, FG	Boreal Forest	0-50 ft. or springs	Perennial streams on site
Beal Mountain	MT	Au, Ag	OP, HL	Boreal Forest	0-50 ft. or springs	Perennial streams on site
Black Pine	MT	Au, Ag, Cu	UG, FG	Boreal Forest	0-50 ft. or springs	Perennial streams on site
Golden Sunlight	MT	Au	UG, OP, VL	Boreal Forest	0-50 ft. or springs	Perennial streams <1 mi. away
Mineral Hill	MT	Au, Ag	UG, VL	Boreal Forest	<200 ft. but >50 ft	Perennial streams on site
Stillwater	MT	PGM	UG, FG, S	Boreal Forest	0-50 ft. or springs	Perennial streams <1 mi. away
Zortman and Landusky	MT	Au, Ag	OP, HL	Boreal Forest	0-50 ft. or springs	Perennial streams on site
Florida Canyon	NV	Au, Ag	OP, HL	Dry/Semi-Arid	0-50 ft. or springs	Perennial streams <1 mi. away
Jerritt Canyon	NV	Au, Ag	UG, OP, HL, VL	Dry/Semi-Arid	0-50 ft. or springs	Perennial streams on site
Lone Tree	NV	Au, Ag	OP, HL, VL	Dry/Semi-Arid	0-50 ft. or springs	Perennial streams >1 mi. away
Rochester	NV	Ag	OP, HL	Dry/Semi-Arid	0-50 ft. or springs	Perennial streams <1 mi. away
Round Mountain	NV	Au, Ag	OP, HL, VL	Dry/Semi-Arid	<200 ft. but >50 ft.	Perennial streams <1 mi. away
Ruby Hill	NV	Au, Ag	OP, HL	Dry/Semi-Arid	0-50 ft. or springs	Perennial streams <1 mi. away
Twin Creeks	NV	Au, Ag	OP, HL, VL	Dry/Semi-Arid	<200 ft. but >50 ft.	Perennial streams on site
Flambeau	WI	Pb, Zn	OP, F	Continental	0-50 ft. or springs	Perennial streams <1 mi. away

The mines studied in detail include one from Alaska, two from Arizona, six from California, two from Idaho, six from Montana, seven from Nevada, and one from Wisconsin. Eighteen mines were primarily gold and/or silver, two were primarily copper or copper molybdenum and one each were platinum group, primary molybdenum, and lead/zinc mines.

Four of the mines selected for study were underground mining operations, while 19 were open pit mining operations. Two were combined open pit and underground mining operations. Five of the mines used flotation (and in some cases gravity) processes exclusively for beneficiation (production of concentrates), two used both flotation and dump leach solvent extraction/electrowinning (SX/EW), and one used dump leach SX/EW processing exclusively. One used flotation with vat leaching processing; while 14 used either heap leaching, vat leaching, or a combination of both processes.

Five mines were located in dry/arid climates, seven in dry/semi-arid climates, eight in boreal forest climates, three in humid subtropical climates and one each in continental and marine west coast climates. Eighteen of the mines selected for study had a depth to groundwater of 0-50 feet or springs on site; four had groundwater depths of between 50 and 200 feet, two had a depth to groundwater of greater than 200 feet, and one had no information on the depth to groundwater. Eleven case study mines had perennial surface water streams on site, seven had perennial streams less than one mile away, six had perennial streams greater than one mile away, and one had no information on the proximity to surface water resources.

The major characteristics of the case study mines were similar to those of all mines with reviewed EISs, as shown in Table 6.3, considering that the availability of information on operational water quality was also a major factor in the selection of case-study mines. The highest percentage of case study mines was from Nevada, and this state had the highest percentage of mines for all major mines, NEPA-eligible mines, and mines with reviewed EISs. Somewhat higher percentages of mines from California and Montana were selected for case studies because of the ease of obtaining operational water quality information from these states.

Similar percentages of gold and/or silver mines were selected for case study as were present in all mines with reviewed EISs. However, a lower percentage of primary copper mines was selected for case study because of the difficulty in obtaining operational water quality information for these facilities. Case study mines and all mines with reviewed EISs had similar distributions of extraction and processing methods. In terms of operational status, no case study mines were in construction, in permitting, or withdrawn because operational water quality information would not be available for mines in these types of operational status.

Case study mines were also similar to all mines with reviewed EISs in terms of EIS elements related to water quality, as shown in Table 6.4. The elements listed in Table 6.3 are considered "inherent" factors that may affect water quality conditions. That is, these elements are related to conditions that are either related to climatic and hydrologic conditions at and near the mine site (in the case of climate, and proximity to water resources) or to qualities of the mined materials that may affect water quality (in the case of acid drainage and contaminant leaching potential). For a number of mines, little or no information on these elements was available in initial EISs, but subsequent NEPA documents either contained the first information or contained improved information after water quality conditions developed at the mine site during and after operation. Therefore, for acid drainage and contaminant leaching potential, the highest documented potential in any of the EISs was recorded.

Case study mines were similar to all mines with reviewed EISs in terms of climate and proximity to surface water resources. When compared to all mines with reviewed EISs, a higher percentage of case study mines had shallower depths to groundwater. However, six of the case study mines had groundwater depths greater than 50 feet below the ground surface. In terms of acid drainage potential, lower percentages of case study mines had low and high acid drainage potential, but higher percentages had moderate acid drainage potential. Therefore, the case study mines provide a somewhat more evenly distributed range of acid drainage potentials than all mines with reviewed EISs. Case study mines had nearly identical percentages of mines with low and high contaminant leaching potential, but more case study mines had moderate acid drainage potential, reflecting fewer mines in the "no information" category for case study mines.

Table 6.3. Comparison of General Categories for All Mines with Reviewed EISs and Case Study Mines (% of mines in subcategory)

Category	Subcategory	All Mines with Reviewed EISs	Case Study Mines
Location	Alaska	10%	4%
	Arizona	11%	8%
	California	11%	24%
	Colorado	0%	0%
	Idaho	9%	8%
	Michigan	0%	0%
	Montana	18%	24%
	Nevada	32%	28%
	New Mexico	3%	0%
	South Carolina	0%	0%
	South Dakota	1%	0%
	Utah	1%	0%
	Washington	0%	0%
	Wisconsin	1%	4%
Commodity	Primary Gold	20%	12%
	Primary Silver	7%	4%
	Gold and Silver	55%	64%
	Copper	20%	4%
	Copper and Molybdenum	1%	4%
	Molybdenum	1%	4%
	Lead and Zinc	6%	4%
	Platinum Group	3%	4%
Extraction Methods	Underground	18%	16%
	Open Pit	72%	76%
	Underground + Open Pit	10%	8%
Processing Methods	Heap and/or Vat Leach	62%	72%
	Flotation and Gravity	27%	28%
	Dump Leach (SX/EW)	11%	8%
	Heap Leach	25%	20%
	Vat Leach	14%	16%
	Heap Leach and Vat Leach	23%	32%
	Smelter	1%	0%
Operational Status	Operating	49%	52%
	Closed	37%	48%
	In Construction	1%	0%
	Permitting	7%	0%
	Withdrawn	6%	0%
Total number of mines		71	25

Table 6.4. Comparison of EIS Elements for All Mines with Reviewed EISs and Case Study Mines (% of mines with sub-element)

Element	Sub-element	All Mines with Reviewed EISs	Case Study Mines
Climate	Dry/Arid	20%	20%
	Dry/Semi-Arid	35%	28%
	Humid Subtropical	4%	12%
	Marine West Coast	4%	4%
	Boreal Forest	28%	32%
	Continental	3%	4%
	Sub-Arctic	4%	0%
Surface Water Proximity	No information	7%	4%
	Perennial Streams >1 mile	26%	24%
	Perennial streams <1 mile	25%	28%
	Perennial streams on site	44%	44%
Groundwater Proximity	No information	12%	4%
	Groundwater >200 ft deep	16%	8%
	Groundwater 50-200 ft deep	13%	16%
	Groundwater 0-50 ft deep/springs on site	59%	72%
Acid Drainage Potential (highest)	No information	9%	8%
	Low	58%	48%
	Moderate	6%	32%
	High	27%	12%
Contaminant Leaching Potential (highest)	No information	22%	12%
	Low	32%	32%
	Moderate	30%	40%
	High	17%	16%
Total number of mines		71	25

Overall, the criteria of having variability in general categories such as geographic location, commodity type, extraction and processing methods and variability in EIS elements related to water quality were met for the selected case study mines. Considering the additional limitation of having readily accessible operational water quality information, the case study mines reflect well the distribution of general categories and water quality-related elements that are present in the larger subsets of hard rock mines in the United States.

6.2.2. ENVIRONMENTAL INFORMATION RELATED TO WATER QUALITY

Table 6.5 shows the mines selected for in-depth study and the variability in their environmental characteristics that may affect water quality. The NEPA information, which was also contained in Section 5, includes geology and mineralization, water quality potential, mitigation, and predicted water quality impacts.

Geology and Mineralization

In terms of geology and mineralization categorizations for the 25 case study mines selected, no or insufficient information was available in the NEPA documents for five mines. Two mines were categorized as having low sulfide content with carbonate present or hosted in carbonate. Eight mines were categorized as having sulfides present with carbonate or moderately high neutralizing-potential rock present and eight were categorized as having sulfides present with no carbonates or carbonates not mentioned or associated with the ore body. One mine was categorized as having high sulfide content with carbonates low or not present.

Table 6.5. Water Quality Characterizations for Case Study Mines.

NEPA EIS Water Quality Category		Greens Creek	Bagdad	Ray	American Girl	Castle Mountain	Jamestown	McLaughlin	Mesquite	Royal Mountain King	Grouse Creek	Thompson Creek	Beal Mountain	Black Pine
		AK	AZ	AZ	CA	CA	CA	CA	CA	CA	ID	ID	MT	MT
Geology and Mineralization		Sulfides present, carbonate or mod-high NP rock present	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body	No/insufficient information available	Gold ore in quartz/magnetite stringers or disseminated. No mention of carbonates	No mention of carbonates; no information on ore mineralogy	No/insufficient information available	No/insufficient information available	Ore in gneiss and granite. No mention of carbonates or sulfides	No/insufficient information available	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body	Sulfides present, carbonate or mod-high NP rock present	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body
Geochemical Characteri-zation and Modeling	Testing Methods	Static, short-term leach, and kinetic tests	Static testing only	No lab/field predictive testing conducted/type unknown	Static ABA and short-term leach tests (WET, SPLP)	Static ABA and short-term leach tests (SPLP)	Short-term leach testing only	Static and short-term leach tests	Static and kinetic tests, whole rock analysis	Static testing only	Static and short-term leach testing conducted	Static, short-term leach, and kinetic testing conducted	Static, short-term leach, and kinetic testing conducted	No information
	Constitutents of Concern	Zinc	Arsenic, fluoride, lead, metals, sulfate	Copper, beryllium, zinc, turbidity, pH	No information	Total dissolved solids	Tailings leachate: barium, arsenic, chromium	Copper	Arsenic, selenium, silver, bismuth, thallium	No information	Lead, arsenic, cyanide, ammonia, nitrate	Cadmium, copper, iron, lead, zinc, selenium, sulfate	Arsenic, cadmium, lead, nitrate, sulfate, cyanide, TDS	Sulfate, copper, zinc, iron, cadmium, low pH
	Predictive Models	Water quality and quantity	None	None	Water quantity	None	None	None	Water quantity and quality	None	Water quantity only	Water quality and quantity	None	None
Water Quality Impact Potential	Acid Drainage	Moderate	Low	No information	Low	Low	Low	Low	Low	Low	Moderate	Moderate	Moderate	High
	Contaminant Leaching	Low	No information	No information	Low	Low	Low	Moderate	Low	No information	Low	Low	Low	Moderate
	Groundwater	Moderate	Low	No information	Moderate	Low	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate	No information
	Surface Water	Moderate	Low	No information available	Low	Low	Moderate	Moderate	Moderate	No information	Moderate	Moderate	Moderate	No information
	Pit Water	No pit lake expected to form	Low/similar to surrounding groundwater	No information	No pit lake expected to form	Low	Moderate	High	Moderate	No information	Moderate	Moderate	No information	No pit lake expected to form
Proposed Mitigations	Groundwater	Groundwater/ leachate capture; Liming, blending, segregation, etc. of PAG material	No information	No information	Source controls without treatment	Groundwater/ leachate capture	Groundwater/ leachate capture; Monitoring or characterization	Monitoring or characterization	Groundwater/ leachate capture; Monitoring or characterization	No information	Monitoring or characterization; Source controls without treatment; Liming, blending, segregation, etc. of PAG material	Monitoring or characterization; Groundwater/ leachate capture	Monitoring or characterization; source controls without treatment; Liming, blending, segregation, etc. of PAG material	Source controls without treatment
	Surface Water	Stormwater/ sediment/ erosion controls; Surface water leachate capture/treatment	Stormwater/ sediment/ erosion controls; Source controls without water capture	No information	Source controls without water capture	Monitoring or characterization; Stormwater/ sediment/ erosion controls; Source controls without water capture	Monitoring or characterization; Stormwater/ sediment/ erosion controls; Source controls without water capture; Surface water/leachate capture/ treatment	Stormwater/sediment /erosion controls; Source controls without water capture; Surface water/ leachate capture/ treatment	Monitoring or characterization; Stormwater/ sediment/ erosion controls; Source controls without water capture	Stormwater/ sediment/ erosion controls	Monitoring or characterization; stormwater/sediment /erosion controls; source controls without water capture	Monitoring or characterization; surface water/ leachate capture/ treatment	Stormwater/ sediment/ erosion controls; source controls without water capture	Monitoring or characterization; stormwater/ sediment/ erosion controls; source controls without water capture
	Pit Water	No pit lake will form	Pit lake prevention	No information	No pit lake will form	Pit lake monitoring; Pit lake prevention	No information	No information	No information	No information	Pit lake prevention	No information	Pit lake prevention	No pit lake will form
	Water Treatment	Treatment for metals and/or acid drainage	No information or none identified	No information or none identified	No information or none identified	No information or none identified	Water treatment for cyanide	No information or none identified	No information or none identified	No information or none identified	Treatment for cyanide, metals and/or acid drainage; treatment in perpetuity	No information or none identified	Water treatment for cyanide	No information or none identified
Predicted Water Quality Impacts	Groundwater	Low	Low	No information	Low	Low	Low	High	Low	No information	Low	Moderate	Low	Low
	Surface Water	Low	Low	No information	Low	Low	Low	Moderate	Low	No information	Low	Moderate	Low	Low
	Pit Water	No pit lake expected to form	No information	No information	No pit lake expected to form	Low	Moderate	High	Moderate	No information	Low/similar to surrounding groundwater	Low/similar to surrounding groundwater	Low/similar to surrounding groundwater	No pit lake expected to form
Discharges	Zero Discharge	No information	No information	No information	Yes	Yes	Yes	No information	No information	No information	Yes	No information	Yes	Yes
	Surface Discharge	Yes	Yes	Yes	No information	No information	No information	Yes	No information	No information	No information	Yes	No information	No information
	Groundwater Discharge	No information	No information	No information	No information	No information	No information	No information	No information	No information	No information	No information	No information	No information

Table 6.5. Water Quality Characterizations for Case Study Mines (continued)

NEPA EIS Water Quality Category		Golden Sunlight	Mineral Hill	Stillwater	Zortman and Landusky	Florida Canyon	Jerritt Canyon	Lone Tree	Rochester	Round Mountain	Ruby Hill	Twin Creeks	Flambeau
		MT	**MT**	**MT**	**MT**	**NV**	**NV**	**NV**	**NV**	**NV**	**NV**	**NV**	**WI**
Geology and Mineralization		High sulfide content, carbonates low/not present	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body	Sulfides present, carbonate or mod-high NP rock present	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body	Sulfides present, carbonate or mod- high NP rock present	Low sulfide content, carbonate present or hosted in carbonate	Sulfides present, carbonate or mod- high NP rock present	Low sulfide content, carbonate present or hosted in carbonate	Sulfides present, carbonate or mod- high NP rock present	Sulfides present, carbonate or mod- high NP rock present	Sulfides present, carbonate or mod- high NP rock present	Sulfides present, no carbonates/ carbonates not mentioned or associated with ore body
Geochemical Characterization and Modeling	Testing Methods	Static, short-term leach, and kinetic tests	Short-term leach and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests	Static, short-term leach, and kinetic tests
	Constitutents of Concern	Aluminum, arsenic, cadmium, copper, zinc, pH, sulfate, calcium, magnesium, chromium, iron, lead, manganese, nickel, selenium, nitrate	Arsenic, cyanide, manganese, nitrate	Nitrate	Aluminum, cadmium, iron, copper, fluoride, zinc, cyanide, metallocyanide complexes, low pH, sulfate, nitrate, arsenic	Aluminum, antimony, arsenic, cadmium, iron, lead, mercury, thallium, TDS, cyanide	Arsenic, selenium, nitrate, sulfate	Arsenic, iron, cyanide, antimony, cadmium, nickel, fluoride, sulfate, TDS	Iron, aluminum, copper, lead, cadmium, zinc, pH	Aluminum, arsenic, fluoride, magnesium, nickel, zinc, antimony, selenium, iron, mercury, lead, manganese, nitrate, sulfate, TDS	Arsenic, aluminum, antimony, TDS, pH	TDS, pH, beryllium, cadmium, selenium, zinc, aluminum, antimony, arsenic, iron, manganese, mercury, nickel, thallium, sulfate	Iron, manganese, sulfate
	Predictive Models	Water quality and quantity	Water quantity only	Water quality and quantity	Water quantity only	Water quantity only	None	Water quality and quantity	None	Water quality and quantity	Water quality and quantity	Water quality and quantity	Water quality only
Water Quality Impact Potential	Acid Drainage	High	Low	Low	High	Low	Moderate	Moderate	Moderate	Low	Low	Moderate	No information
	Contaminant Leaching	High	Moderate	Moderate	Moderate	High	Moderate	High	Moderate	High	Moderate	High	Moderate
	Groundwater	High	Moderate	Low	Moderate	High	Moderate	Low	Moderate	High	Low	Moderate	Moderate
	Surface Water	Low	Low	Low	High	No information	Moderate	Moderate	Moderate	Moderate	Low	High	Moderate
	Pit Water	High	No pit lake expected to form	No pit lake expected to form	No information	No information	No pit lake expected to form	High	No pit lake expected to form	Moderate	No pit lake expected to form	High	High
Proposed Mitigations	Groundwater	Monitoring or characterization; Source controls without treatment; Ground-water/ leachate capture with treatment; In-perpetuity capture and/or treatment; Long-term fund	Groundwater/ leachate capture with treatment	Monitoring or characterization; Source controls without treatment; Groundwater/ leachate capture with treatment	Monitoring or characterization; Source controls without treatment; Groundwater/ leachate capture with treatment; Liming, blending, segregation, etc. of PAG material	Source controls without treatment; Liming, blending, segregation, etc. of PAG material	Source controls without treatment; Liming, blending, segregation, etc. of PAG material	Monitoring or characterization; Groundwater/ leachate capture with treatment	No information	Source controls without treatment	Source controls without treatment	Monitoring or characterization; Source controls without treatment; Liming, blending, segregation, etc. of PAG material	Source controls without treatment; groundwater/ leachate capture with treatment
	Surface Water	Surface water/ leachate capture/ treatment; Surface water augmentation/ replacement	No information	Monitoring or characterization; Stormwater/ sediment/ erosion controls; Source controls without water capture	Monitoring or characterization; Stormwater/ sediment/ero-sion controls; Source controls without water capture; Surface water/ leachate capture/ treat-ment; In-perpetuity cap-ture/ treatment	Source controls without water capture	Stormwater/ sediment/ erosion controls; Source controls without water capture; Surface water/ leachate capture/ treatment	Stormwater/ sediment/ erosion controls; Source controls without water capture	Stormwater/ sediment/ erosion controls	Stormwater/ sediment/ erosion controls	Stormwater/ sediment/ erosion controls	Monitoring or characterization; Stormwater/ sediment/ erosion controls	Source controls without water capture; Surface water/ leachate capture/ treatment
	Pit Water	Treatment of pit water or backfill amendment	No pit lake will form	No pit lake will form	Pit lake prevention	Pit lake prevention	Pit lake prevention	Pit lake prevention	No pit lake will form	Pit lake monitoring	No pit lake will form	Pit lake monitoring	Pit lake prevention
	Water Treatment	Water treatment in perpetuity	Water treatment using non-conventional approaches	Water treatment using non-conventional approaches	Treatment for cyanide, metals and/or acid drainage; Non-conventional approaches; Treatment in perpetuity	No information available or no water treatment measures identified	No information available or no water treatment measures identified	Treatment for cyanide, metals and/or acid drainage; Treatment using non-conventional approaches	No information available or no water treatment measures identified	No information available or no water treatment measures identified	No information available or no water treatment measures identified	Water treatment for metals and/or acid drainage	Water treatment for metals and/or acid drainage
Predicted Water Quality Impacts	Groundwater	High	Low	Low	High	Low	Low	Low	Low	Low	Low	Low	Low
	Surface Water	Low	Low	Low	High	Low	Low	Low	Low	Low	Low	Low	Low
	Pit Water	High	No pit lake expected to form	No pit lake expected to form	High	No pit lake expected to form	No pit lake expected to form	High	No pit lake expected to form	Moderate	No pit lake expected to form	High	High
Discharges	Zero Discharge	No information	No information	No information	No information	Yes	No information	No information	No information	Yes	Yes	No information	No information
	Surface Discharge	No information	Yes	Yes	Yes	No information	No information	Yes	No information	No information	No information	Yes	Yes
	Groundwater Discharge	No information	No information	Yes	No information	No information	No information	No information	No information	No information	No information	Yes	No information

Geochemical Characterization and Modeling

In terms of geochemical characterization and modeling categorizations for the 25 case study mines selected, no or insufficient information was available in the NEPA documents for two mines. Static testing only was performed at two mines and short-term leach testing only at one mine. Static and short-term leach testing were performed at three mines. Static and kinetic testing was conducted at one mine and short-term leach and kinetic testing conducted at one mine also. Static, short-term leach and kinetic testing were conducted at 14 mines.

No information was available on constituents of concern in the NEPA documents for two of the case study mines. The other mines identified a variety of constituents that can be categorized as metals (19 mines), metalloids (14 mines), sulfate (10 mines), nitrogen compounds (eight mines), cyanide (six mines) and other conventional pollutants (11 mines).

No predictive models were used according to the NEPA documents for nine of the 25 case study mines. Only water quantity predictive models were used at four mines while only water quality predictive models were used at one mine. Both water quantity and water quality predictive models were used as a part of the NEPA process at ten mines.

Water Quality Impact Potential

No information on acid drainage potential was contained in the NEPA documents for two of the case study mines. Low acid drainage potential was identified at eleven mines, moderate acid drainage potential at eight mines and high acid drainage potential at three mines.

No information on contaminant leachate potential was contained in the NEPA documents for three of the case study mines. Low contaminant leaching potential (leachate does not exceed water quality standards) was identified at six mines. Moderate potential for elevated contaminant concentrations (leachate exceeds water quality standards by 1-10 times) was identified at 11 mines. High potential for elevated contaminant concentrations (leachate exceeds water quality standards by over 10 times) was identified at four mines.

Groundwater impact information was not available in the NEPA documents for three of the case study mines. Low groundwater quality impacts (< relevant standards) were identified at four of the mines. Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) were identified at 12 of the mines. High groundwater quality impacts (>10 times relevant standards) were identified at five of the mines,

Surface water impact information was not available in the NEPA documents for five of the case study mines. Low surface water quality impacts (< relevant standards) were identified at six of the mines. Moderate surface water quality impacts (≥ and up to 10 times relevant standards) were identified at 11 of the mines. High surface water quality impacts (>10 times relevant standards) were identified at two of the mines.

Pit water impact information was not available in the NEPA documents for five of the case study mines. Low pit water quality impacts (water quality similar to surrounding groundwater or < relevant standards) was identified at one mine. Moderate pit water quality impacts (≥ and up to 10 times relevant standards) were identified at four mines. High pit water quality impacts (>10 times water quality standards) were identified at six mines. No pit lake was expected to form (pit above water table or no pit) at eight mines.

Proposed Mitigation

Groundwater mitigation information was not available or no mitigation were identified in the NEPA documents for four of the case study mines. Groundwater monitoring or characterization of mined materials was identified as a mitigation at 11 mines. Source controls without treatment (liners, leak detection systems, run on/off controls, caps/covers, adit plugging) was identified as a mitigation at 13 mines. Groundwater/leachate capture with treatment was identified as a mitigation at nine mines. Perpetual groundwater capture and/or treatment and/or a long-term mitigation fund were identified as mitigation measures at one mine. Liming, blending, segregation, etc. of potentially acid-generating (PAG) material was identified as mitigation at seven mines.

Surface water mitigation information was not available or no mitigation were identified in the NEPA documents for two of the case study mines. Surface water monitoring was identified as a mitigation measure at seven mines. Stormwater, sediment or erosion controls were identified as mitigation measures at eighteen mines. Source controls not involving capture of water (including liners, adit plugging, caps/covers, leak detection systems, spill prevention measures, and liming/blending/segregating of PAG materials) were identified as mitigation at twelve mines. Surface water/leachate capture and/or treatment (including settling, land application, routing of water, seepage collection) was identified as a mitigation at 10 mines. Perpetual surface water capture and/or treatment were identified mitigation measures at one mine.

Pit water mitigation information was not available or no mitigation were identified in the NEPA documents for five of the case study mines. Pit lake monitoring was identified as a mitigation measure at two mines. Pit lake prevention (backfill, pumping, stormwater diversion, use in mine operation) was identified as a mitigation at nine mines. Treatment of pit water or backfill amendment (e.g., lime addition) was identified as a mitigation at one mine. No pit lake was expected to form (underground mine or pit above water table) at seven mines.

Water treatment information was not available or water treatment was not identified in the NEPA documents for twelve of the case study mines. Water treatment for cyanide was identified as a mitigation approach at five mines. Water treatment for metals and/or acid drainage was identified as a mitigation measure at seven mines. Water treatment using non-conventional approaches was identified as a mitigation method at four mines. Perpetual water treatment to meet discharge standards was identified as a mitigation at three mines.

Predicted Water Quality Impacts

Predicted groundwater quality impact information was not available in the NEPA documents for two of the case study mines. Low groundwater quality impacts (< relevant standards) were predicted at 17 of the mines. Moderate groundwater quality impacts (≥ and up to 10 times relevant standards) were predicted at one mine. High groundwater quality impacts (>10 times relevant standards) were predicted at four mines.

Predicted surface water quality impact information was not available in the NEPA documents for two of the case study mines. Low surface water quality impacts (< relevant standards) were predicted at 18 of the mines. Moderate surface water quality impacts (≥ and up to 10 times relevant standards) were predicted at three of the mines. High surface water quality impacts (>10 times standards) were predicted at one mine.

Pit water quality impact information was not available in the NEPA documents for four of the case study mines. Low pit water quality impacts (concentrations less than relevant standards), or water quality similar to surrounding groundwater were predicted at four mines. Moderate pit water quality impacts (≥ and up to 10 times relevant standards) were predicted at two mines. High pit water quality impacts (>10 time relevant standards) were predicted at six mines. No pit lake (underground mine or pit bottom above water table) was expected to form in eight of the mines.

Discharges

Two case study mines had groundwater discharges, suggesting that 20 of the mines were not expected to have groundwater discharges. Thirteen case study mines had surface water discharges with various forms of NPDES permits, while 12 were not expected to have surface water discharges. Seven mines were identified as "zero discharge" facilities.

6.3. PREDICTED AND ACTUAL WATER QUALITY AT THE CASE STUDY MINES

Summaries for the 25 case study mines are contained in Section 6.3. Ownership, commodities, extraction and processing types, years of operation, acres disturbed, and financial assurance amounts are summarized for each case study mine. Information related to water quality predictions and conditions is summarized in three sections: water quality predictions summary, which contains information from the NEPA documents reviewed; actual water quality conditions; and comparison of predicted and actual water quality conditions. More detailed information on the case study mines is contained in Appendix B Case Study Detailed Information, especially on environmental quality information from the NEPA documents and actual water quality conditions.

6.3.1. GREENS CREEK, ALASKA

The Greens Creek mine, owned by Kennecott Minerals Corporation (70%) and Hecla (30%), has been in operation since 1984. The primary commodities mined are gold, silver, lead and zinc from underground mining and flotation and gravity processing operations. It disturbs 170 acres on Tongass National Forest lands in Forest Service Region 10 (actually within a National Monument). It has a current financial assurance amount of $26.2 million.

6.3.1.1. WATER QUALITY PREDICTIONS SUMMARY

The Tongass National Forest was the lead agency for all NEPA actions at the Greens Creek Mine. NEPA was required for the new project to be permitted, and an EIS was completed in 1983. NEPA was not required by the EPA for the NPDES discharge permit. Subsequent EAs for general operation and waste rock expansion were conducted in 1988 and 1992, respectively. In 2003, an EIS was conducted for tailings disposal. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1983 EIS

The 1983 EIS contains no specific mention of any specific geochemistry field or lab tests performed, however the EIS did identify the potential for the project to degrade surface and/or groundwater as a result of acid drainage. Increased concentrations of total dissolved solids and sulfate were predicted for groundwater in general (no specific mention was made about the basis of this prediction or the actual increased concentrations), but surface water concentrations were predicted to meet regulatory standards due to high dilution (greater than 68:1). Excess tailings liquids and other mine-related discharges were to be released from sediment basins and ponds without further treatment to the marine environment.

1988 EA

The 1988 EA specifically cited the results of “preliminary” lab tests, including sulfur determinations, biological tests and column leach tests performed in 1982 and 1985, as an indication that the tailings would not produce acid drainage. Only one tailings sample was analyzed for acid drainage potential.

1992 EA

The 1992 EA described geochemical tests, including metals analysis, acid-base accounting, synthetic precipitation leach tests and leachate modeling. The results indicated that some waste rock had the potential to be acid-producing, but a greater portion was shown to be acid-neutralizing; Overall, no net acid drainage production was expected from waste rock. Zinc concentrations in waste rock leachate (using existing waste rock material) were predicted to be high (0.5 – 1.3 mg/l), based on the synthetic precipitation leach tests, while other metals concentrations were predicted to be low.

2003 EIS

The 2003 EIS did not address waste rock issues. The 2003 EIS included a hydrology and geochemistry evaluation of the tailings facility in the Appendix. The evaluation included both static and long-term testing. According to the text, static test results indicated that the tailings were potentially acid generating (all static test results indicated an AGP:ANP ratio of greater than 1.0). However, based on humidity cell tests it was concluded that the tailings would not produce acid drainage, although the evaluation acknowledged some inconsistencies in the results. Predictions based largely on oxidation rates projected lag times for acid drainage generation of 10 to 33 years. According to the EIS, reclamation and closure methods would slow or stop the weathering process (e.g., oxidation rates) so that acidification would not occur.

The prediction of no significant acid drainage in the evaluation relied upon the use of a mass loading model (Excel© spreadsheet with Palisade@Risk©) to simulate water quality downgradient from the tailings facility. Modeling results predicted the tailings would remain alkaline for at least 500 years while acknowledging that the prediction of rates of oxidation and acidification are complex and acidic conditions could exist in the tailings. The primary mitigation employed was an engineered soil cover to reduce acidification risk by through reduction of oxygen infiltration.

6.3.1.2. ACTUAL WATER QUALITY CONDITIONS

According to the 1992 EA, actual runoff from the waste rock piles was reported to have an average zinc concentration of 1.65 mg/l.

The hydrology and geochemistry evaluation in the 2003 EIS contained some site water chemistry information that can be used to verify the previous and existing water quality predictions. Tailings facility water had relatively neutral pH values (7.8 to 8.0), increased sulfate concentrations (1,800 to 2,000 mg/l) and low metals concentrations (0.01 mg/l zinc) in the tailings saturated zone. However, underdrain water quality showed some moderate acidity (pH 6.5 to 6.7), generally lower sulfate concentrations (800 to 2,000 mg/l) and higher zinc concentrations (1-2 mg/l) and in the tailings unsaturated zone, new tailings showed lowered pH (5.8 to 6.6) and increased sulfate (2,300 to 2,400 mg/l) with higher zinc concentrations (0.1 – 3.6 mg/l) and additionally significantly increased copper, lead and selenium. Old unsaturated tailings showed a neutral pH (7.5) but high concentrations of sulfate (17,000 mg/l) along with increased concentrations of metals (zinc and magnesium).

According to the 2003 EIS, groundwater quality monitoring wells monitored from 1988 to 2000 have not indicated increasing metal and sulfate levels or acidity so far, although anomalously high sulfate concentrations are noted. Surface water quality monitoring similarly indicates no impacts to surface water quality although some evidence of increased cadmium, copper, mercury and zinc greater than Alaska Water Quality Standards were noted in the late 1980's and 1990. However, the EIS contradicts itself by acknowledging that lower pH, higher sulfate and increased zinc concentrations are evident in some smaller streams. The EIS speculated that the increased concentrations were due to sulfide material (tailings or waste rock) lying outside the tailings pile capture area. The potential for long-term acid drainage from the tailings was mentioned in the 2003 EIS, but impacts occurred in less than 20 years rather than in greater than 500 years.

No reports or notices of violations related to water quality were noted.

6.3.1.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.6 provides a summary and comparison of potential, predicted and actual water quality information for the Greens Creek mine. The accuracy of the predictions is discussed in this section.

Table 6.6. Greens Creek, AK, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings	• 1983 EIS: Increased concentrations of sulfate and TDS in groundwater but no impact to surface water and marine waters due to mitigation • 1988 EA: Testing indicates no potential for acid drainage • 2003 EIS: Tailings have long-term potential for acid drainage	• 1983 EIS: Surface water and marine water dilution adequate to meet standards • 2003 EIS: acid drainage to be mitigated by short-term capture of tailings solution and long-term by reclamation and closure • grade and cap tailings	• 1983 EIS: No impacts to surface water or marine water predicted • 2003 EIS: No impacts from acid drainage for at least 500 years	• 2003 EIS: Old unsaturated tailings leachate, new tailings leachate, and underdrain water quality all show evidence of acidity and increased sulfate and zinc and in some cases copper, lead, magnesium and selenium • 2003 EIS: Surface water quality monitoring indicates some evidence of lower pH and increased cadmium, copper, mercury, sulfate and zinc due to high sulfide material (tailings or waste rock) lying outside the tailings pile capture area
	Waste Rock	• 1992 EA: Some waste rock has the potential to be acid drainage producing but a greater portion is acid drainage neutralizing, with a prediction of no net acid drainage generation from waste rock. • 1992 EA: Zinc concentrations for waste rock leachate predicted to be high (0.5 – 1.3 mg/l) and other metals concentrations low.	• 1983 EIS: Surface water and marine water dilution adequate to meet standards. • 1992 EA: Mixing of waste rock to neutralize acid drainage potential 2003 EIS: Backfilling of waste rock into underground mine	• 1983 EIS: No impacts to surface water or marine water predicted • 1992 EA: No impacts to surface water or marine water predicted	• 1992 EA: Actual runoff from the waste rock piles was reported to have an average zinc concentration of 1.65 mg/l. • 2003 EIS: lower pH, higher sulfate, and increased zinc concentrations are evident in some smaller streams possibly due to high sulfide material (tailings or waste rock) lying outside the tailings pile capture area

<u>Tailings Seepage and Waste Rock Runoff</u>: The observed acidic and metal-rich drainage seeping from the tailings impoundment and the observed high zinc concentrations in waste rock runoff were not predicted in the 1988 EA. In this EA, geochemical testing indicated no potential for acid drainage. The 2003 EIS predicted long-term potential for acid drainage in tailings (10 to 33 years, based on ABA tests), but the post- mitigation (following installation of reclamation covers) prediction, using modeling, indicated that this would not occur for at least 500 years. The long-term potential for acid drainage from tailings occurred in less than 20 years. Therefore, the observed acidic, metal-rich seepage from tailings entering smaller streams mentioned in the 2003 EIS was not accurately predicted in the 1988 EA. The 1992 EA estimated, based most likely on existing leachate concentrations, that zinc concentrations in the expanded waste rock leachate material would be high (0.5 – 1.3 mg/l) but that net drainage from the waste rock would not be acidic. No subsequent information on waste rock leachate concentrations has been obtained to determine if values from the expanded facility are within the predicted range.

Surface water quality impacts: The observed lower pH and increased metal and sulfate concentrations in surface water were not predicted by the EISs. The 1983 EIS predicted that dilution would prevent impacts to surface water. Therefore, the observed surface water quality impacts were not accurately predicted.

6.3.2. BAGDAD, ARIZONA

The Bagdad mine, wholly owned by Phelps Dodge Corporation, is an historic mine that has been in operation since before 1960. The primary commodities mined are copper and molybdenum from open pit mining and flotation and dump leach processing operations. It disturbs approximately 4,424 acres on private land and BLM lands. It has a current financial assurance amount of $12.7 million.

6.3.2.1. WATER QUALITY PREDICTIONS SUMMARY

The BLM has been the lead agency for all NEPA actions at the Bagdad mine. NEPA was not required for the historic mining project to be permitted and was not required by the EPA for the NPDES discharge permit. An EIS was completed in 1996 for only impacts related to the expansion of the mill tailings and waste rock storage areas. The following sections summarize the water quality predictions made in the NEPA document reviewed as well as information on actual water quality.

1996 EIS

The 1996 EIS included information on total sulfur, pyritic sulfur and NP/AP (ABA) testing. Increased (greater than background) concentrations of arsenic, fluoride and lead were noted along with elevated levels of other metals and sulfate. No predictive modeling was performed. According to the EIS, potential adverse groundwater impacts from tailings water would be minimal, and impacts to surface water were predicted to be low, due to construction design of the tailings facilities. The low potential for acid mine drainage was illustrated by the overall quality of the pit water, which had relatively low concentrations of metals and sulfate in a highly mineralized area. The overall quality of the water was described as good with only a few measurements of metals and fluoride that exceeded Aquifer Water Quality Standards. Exceedences were also found in groundwater samples from non-disturbed areas of the mine, suggesting that elevated background concentrations of arsenic, fluoride and lead exist in the groundwater in the Bagdad region.

According to the EIS, mitigation would consist of the majority of the tailings water evaporating off the surface of the facility. Toe channels and underdrains around the South waste rock dump would be used to prevent the percolation of surface water through the facility to minimize infiltration into the aquifer. Surface runoff would be promoted by using grading and a cap. Stormwater diversions would be implemented. Horizontal dewatering wells were proposed to limit water entering the pit and lower the potential for sulfide ore oxidation. The proposed South waste rock disposal facility was not expected to adversely impact groundwater quality, and no impacts to water quality of Francis Creek, Burro Creek, or Big Sandy River were predicted.

6.3.2.2. ACTUAL WATER QUALITY CONDITIONS

Surface water quality monitoring data from the Arizona Department of Environmental Quality (ADEQ) for 1991 to 2004 was obtained and reviewed. In addition, information from an EPA report on damage cases (U.S. EPA, 1997) provided information on releases from the Cyprus Bagdad Mine. The records show that prior to and following the 1996 EIS, water quality impacts had been noted at the site including the following:

- In May-June of 1991, a tailings impoundment failed and discharged to Copper Creek. Elevated concentrations of mercury, phenols, ammonia, copper and acidity occurred in Boulder and Copper creeks, resulting in a fish kill. Boulder Creek was diverted around the spill, and the contamination was reportedly cleaned up.

- In 1991 and 1992 samples were taken from various surface water resources (Boulder Creek, Wilder-Burro Creek, Copper Creek), which showed periodic exceedences of water quality standards for arsenic, beryllium copper, lead, mercury, pH and turbidity. Contaminant sources were not identified.
- From 1998-2002, samples were taken from similar surface water resources (Boulder Creek, Burro Creek, Butte Creek) with periodic exceedences of water quality standards for arsenic, copper, lead, mercury, selenium and turbidity. Contaminant sources were not identified, but exceedences occurred at Phelps Dodge monitoring points.
- In May 1991, seepage of pregnant leach solution from the Copper Creek Leaching System was discovered in a receiving pool in Boulder Creek Studies indicated that instead of being contained by the Copper Creek Flood Basin, the heavily contaminated solution seeped under the dam The concentration of total copper in samples collected in the pool in Boulder Creek was as high as 76.4 mg/l. Out of 18 samples collected from the pool during the month that the seepage was discovered, every sample exceeded background copper levels by more than 0.5 mg/l, the state's Agricultural Livestock Watering Standard for total recoverable copper. No information was available in the files reviewed that clearly documented the source of the infiltration; however, several documents referred to "repairs" to various HDPE liners. It was not clear from information in the files precisely which units were lined, when they were lined, or the capacity or dimensions of the units.
- On March 29, 1993, U.S. EPA issued a Finding of Violation and Order against Cyprus. On September 13, 1996, the U.S. Department of Justice brought civil action against Cyprus for discharging contaminated water in violation of the Clean Water Act and Arizona law. The civil action cited discharges from tailings ponds, pipelines, leach dumps, other facilities and a sewage treatment plant. The largest discharges cited, however, came from the mine's Copper Creek Leaching Basin. In a Consent Decree, Cyprus agreed to pay a civil penalty totaling $760,000.
- Of 143 samples of water collected from January 1992 until October 1993, all of which were collected from sumps installed in the alluvial gravels of Boulder Creek downgradient from the facility, not one sample showed any elevation above background concentrations of copper. The cutoff wall was credited with reducing total copper concentrations in shallow ground water 400 feet downgradient of the wall from 7.2 mg/l before the wall was constructed to 0.8 mg/l afterwards. ADEQ personnel concluded in an internal 1995 memorandum that the overall effectiveness of the remedial measures undertaken by Cyprus was amply demonstrated by the consistently low concentrations of copper measured in sumps downgradient of the wall and the consistently within-standard copper values achieved in the receiving pool. As of November 1996, the available water quality enforcement files did not contain any more information regarding how Cyprus is managing it's PLS pond and other structures.

6.3.2.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.7 provides a summary and comparison of potential, predicted and actual water quality information for the Bagdad mine. The accuracy of the predictions is discussed in this section.

The 1996 EIS identified the potential for acid drainage and other impacts, and suggested that existing water quality did not demonstrate impacts because background water quality had exceedences. The EIS specifically predicted that there would be no impacts to the water quality of Francis Creek, Burro Creek or Big Sand River. However, exceedences of water quality standards were observed in Burro Creek between Francis Creek and Boulder Creek after the 1996 EIS. Therefore, assuming that the source of the exceedences is the mine, the observed water quality was not accurately predicted in the EIS.

Table 6.7. Bagdad, AZ. Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Surface Water	Tailings	1996 EIS: • Potential for acid drainage and other impacts indicated in testing. • Existing water quality does not indicate impacts. • Background water quality indicates natural exceedences.	1996 EIS: • Facility design to prevent groundwater and surface water impacts. o Stormwater diversions o Grade and cap surface o Leachate collection	1996 EIS: • No impacts to water quality of Francis Creek, Burro Creek or Big Sandy River are predicted.	WQ Monitoring (1998-2002): • Boulder Creek: exceedences for arsenic, lead, mercury, and selenium • Burro Creek: exceedences for copper and mercury Butte Creek: exceedences for mercury and selenium

6.3.3. RAY MINE,ARIZONA

The Ray mine owned by ASARCO has been in operation since 1948. It is projected to continue operations until 2044. The primary commodities mined are copper and silver from open pit mining and flotation and gravity and dump leach processing operations. It disturbs 6,231 acres on private land. It has a financial assurance amount of $784,826.

6.3.3.1. WATER QUALITY PREDICTIONS SUMMARY

The BLM has been the lead agency for all NEPA actions at the Ray mine. NEPA was not required for the historic mining project to be permitted and was not required by the EPA for the NPDES discharge permit. An EIS was completed in 1999 only for the impacts related to a proposed land exchange that would enable the mining company to eliminate public lands from within and adjacent to areas of ongoing mine development. The following sections summarize the water quality predictions made in the NEPA document reviewed. Information on actual water quality is discussed in the following section.

1999 EIS

The EIS was completed for a land exchange. No geochemical tests or models were mentioned in the EIS, and as a result, no information on acid drainage potential or contaminant leaching potential was provided. The mine is a porphyry copper deposit.

According to the EIS, the foreseeable mining uses on the selected lands will likely affect groundwater. Similarly, the foreseeable mining uses on the selected lands would result in impacts to surface water sources and features. Impacts to surface water sources and features are not currently known. However, the EIS stated that it is not possible to describe specific details concerning groundwater or surface or water quality impacts because a detailed mine plan has not been developed and because specific designs and measures that may minimize impacts to surface water and groundwater sources and features are not currently known .

6.3.3.2. ACTUAL WATER QUALITY CONDITIONS

Groundwater monitoring data from 1990 to 1994 were obtained from the Arizona Department of Environmental Quality (ADEQ), and information on violations and water quality exceedences from 1990 through 1996 were obtained from U.S. EPA (1997: Damage Cases). Information from both sources indicates the following:

- Due to a spill or spills in 1990, TDS, ammonia, arsenic and copper concentrations exceeded standards along a 14 to 50 mile stretch of the Gila River. Exceedences of up to eight times the standard were noted.
- Tributary headwater streams (Mineral Creek) showed exceedences of arsenic, beryllium, copper and turbidity during the period 1990-1994, and elevated concentrations of copper and zinc in sediment were also noted.
- An ADEQ complaint investigation conducted from 1991-1994 in Mineral Creek from the headwaters to the Gila River, revealed that at multiple sites sampled around the Ray Mine and Gibson Mine, uses were impaired by arsenic, beryllium, copper, low pH, and zinc.
- An EPA copper mine study in 1992 showed that two sites in Mineral Creek had uses impaired by copper and low pH.
- From August 1990 through November 1993, at least 19 spills of hazardous materials were reported at the ASARCO Ray Mine. The majority of spills were from dams, pipelines and ponds. The discharges typically resulted from either accidental releases associated with heavy rain or from chronic seepage from leach facilities to groundwater, which then entered the creek. As a result, surface water quality has been significantly affected. A total of 41 violations of total copper, dissolved copper, and beryllium numeric surface water quality standards was documented by the Arizona Department of Environmental Quality (ADEQ), EPA, and ASARCO in Mineral Creek below the Ray Mine.
- On March 30, 1995, ASARCO noted a low pH reading in Mineral Creek. Upon investigation, ASARCO discovered that a 30-inch gravity flow transit pipeline was leaking. The next day, an HPDE line to the Ray concentrator came apart at the flanged end and released approximately 150,000 gallons of fresh water.
- Unauthorized discharges of Ray Unit process waters to Mineral Creek and Elder Gulch have occurred many times in recent years, including numerous violations of permit effluent limits. During one eight-month period from January to August 1993, nine spills occurred at the mine that resulted in unauthorized discharges to Mineral Creek. The specific causes included overflows, equipment failures and damage caused by heavy machinery. Ambient water quality sampling data have documented non-compliance with water quality standards in Mineral Creek for a variety of metals. Copper concentrations as high as 2.7 mg/l were reported in creek waters below the mine. In 1993, copper concentrations in the creek above 1 mg/l were recorded in May, June, July, August and September. Water quality violations were documented in the same stretch of the creek for beryllium. In March 1993, discharges from a tributary of Mineral Creek that also drains the Ray Unit, Elder Gulch, exceeded standards for hexavalent chromium, sulfide, and total arsenic.
- In December 1992 and January 1993, heavy rains caused the Gila River to breach the AB-BC tailings impoundment containment dike 13 times in January 1993, eroding through the dike and into the toe of the tailings pile. The total discharge was approximately 292,000 tons (216,000 cu yd) of tailings. Sampling of the river showed that elevated concentrations of pollutants occurred at least 11 miles downstream of the spill. The tailings formed bank and bottom deposits in the river, impairing both recreational uses and the quality of habitat for plants and animals. The discharge also had an adverse effect on the sediment loading of the river and stream morphology.

In July 1996, the Arizona Department of Environmental Quality (ADEQ) reported that approximately one-half mile of the Mineral Creek stream bed below the Ray Mine was visibly affected by mining activities. The cobble and gravel substrate was coated with a blue-green layer of copper oxides. According to ADEQ, visible environmental damage to Mineral Creek constitutes a violation of narrative surface water quality standards. quality standards for beryllium, cadmium and copper were also violated in Mineral Creek in April 1996. ADEQ termed the violations a dramatic degradation of water quality by mining activities. In addition, groundwater standards for arsenic, cadmium, pH and beryllium were exceeded in three wells. In April 1995, EPA reported that six groundwater wells downgradient of the electrowinning plant and the electrowinning dam were continuously pumping pregnant leach solution. EPA concluded that it is likely that contaminants are escaping from the Ray Unit and entering Mineral Creek via groundwater.

6.3.3.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.8 provides a summary and comparison of potential, predicted and actual water quality information for the Ray mine. The accuracy of the predictions is discussed in this section.

The 1999 EIS did not provide any information on potential impacts to water quality, with the only mitigation being that all affected water would be captured in the open pit. It did not address the numerous and serious past or existing surface water, groundwater and stream habitat impacts from mine operations. Prior to the 1999 EIS, Ray mine operations did result in degradation of surface water in Mineral Creek and the Gila River with ammonia, arsenic, beryllium, copper, low pH, total dissolved solids, turbidity and zinc.

Table 6.8. Ray, AZ, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings	1999 EIS: • No information provided	1999 EIS: • All affected water to flow towards the open pit capture zone	1999 EIS: • Impacts to groundwater and surface water predicted, but details cannot be described because a detailed mine plan has not been developed.	WQ Monitoring: • Prior to the 1999 EIS significant impacts to surface water and groundwater were identified as a result of tailings spills, leaking pregnant leach solution and other sources

6.3.4. AMERICAN GIRL, CALIFORNIA

The American Girl Mine is owned by MK Gold Company (50%) and Hecla Mining Company (50%). Operations were started in 1995, and the mine closed in 1996. Gold and silver were produced from both underground and open pit operations and were processed using vat leach (for gold) and cyanide heap leach (for silver) methods. It disturbs 155 acres of BLM land in Imperial County and has a current financial assurance amount of $278,750.

6.3.4.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA and CEQA were required for the project to be permitted. An older EA was completed in 1988, and EIS/EIR was completed in 1994. No subsequent NEPA or state equivalent environmental assessments were performed for the project. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1988 EA

Annual precipitation is 3 to 4 inches per year, and evaporation in nearby cities is 100 to 119 inches annually. All the surface drainages in the area are ephemeral, with flows occurring only during and following major precipitation events. Groundwater in the vicinity of the proposed heap leach pad occurs from 80-240 feet bgs.

Gold ore is in quartz/magnetite stringers in metasedimentary and igneous rock. No field or laboratory tests were performed. A water quantity model was performed to predict the amount of drawdown in the groundwater table. No information was provided on acid drainage potential, contaminant leaching potential, or constituents of concern.

A background groundwater quality evaluation showed that TDS, chloride and fluoride concentrations exceeded drinking water standards. Two potential groundwater impacts were identified: drawdown of groundwater in the alluvial deposits due to withdrawal for operations, which could influence surrounding groundwater users, and groundwater quality influences resulting from the heap leach operations. The proposed mine was determined to have no identifiable impact on surface water resources, because surface waters flows only during major precipitation events.

The heap leach pad was proposed to be lined. Ore processing (mill and heap leach) operations were planned to be operated as zero discharge facilities. Inflow of groundwater to mine pits/underground areas was expected to be consumed in zero-discharge project operations (dust control, process water, etc.), which would avoid seepage of contaminated water into groundwater. Diversion ditches above the mining areas were proposed to channel water around active mining and waste rock disposal areas. Sediment traps would be installed, if required, during construction.

No impact to groundwater was predicted with proper installation and operation of the lined pad facility. Even if leachate from the pad bypasses the liner, groundwater impacts were predicted to be minimal, as the leachate would reach the saturated zone after a long travel time, allowing the leachate to be naturally attenuated. The American Girl Canyon Project was predicted to have no identifiable impact on groundwater quality, and other alternatives were expected to have no impact as well. The proposed alternative was also predicted to have no identifiable impact on surface water resources, as surface waters flow only during major precipitation events. In the underground test adit, the first inflows were encountered at an elevation of about 510 above msl, just above the base of the proposed open pits. Therefore, the pit is not expected to contain permanent water after mining.

No information was provided on discharges to groundwater or surface water.

1994 EIS

The mine area is arid, has low amounts of precipitation, arid winds, high temperatures, and a high percentage of sunshine in a desert environment. Average on-site precipitation is 2.14 inches, and at Yuma station, annual evaporation is 97.66. No evaporation data were collected on site. All surface drainages in the area are ephemeral. Flash flooding and sediment-laden flow are common and result in shifting of drainage channel positions. Groundwater in the vicinity of the proposed project occurs in the alluvium of Tumco and American Girl Washes, and in the unconsolidated deposits underlying Pilot Knob Mesa. The depth to groundwater was variable. The bedrock groundwater table was generally 100 ft deep in the American Girl Wash. Exploration holes drilled to depths of 500-600 ft bgs have significantly lower water levels. Groundwater in the vicinity of the existing leach pad and open-pit occurs at a depth ranging from 35-240 ft bgs. The Padre Madre Wash had drill holes completed to depths of at least 200 ft below the base of the canyon floor, and they were dry. The Tumco Wash exploration holes were dry to the 500 ft elevation with some seeps and inflows below this elevation. Water has been encountered in exploration holes at depths of 700 ft Depths to groundwater in the Pilot Knob Mesa range from 200-400 ft.

Mineralization has a strong quartz-magnetite association and is characterized by irregular stringer zones containing the two minerals. High grade zones may occur as semi-massive lenses up to several feet thick. Gold occurs within the magnetite-quartz stringers or is disseminated in the surrounding wall rock. Geochemical testing of waste materials from the Padre Madre and American Girl Canyon mine operations have shown little potential to generate acid or leach metals or other constituents at concentrations of concern for waste characterization or water quality. Waste Extraction Test (WET) results for the Oro Cruz tailings would be classed as a Class C (inert) waste. The Oro Cruz tailings and spent ore would not be acid generating (total sulfur less than 0.01%). EPA Method 1312 (SPLP) tests showed that the Oro Cruz tailings would not leach metals or other constituents of concern to surface water or groundwater. Due to the degree of oxidation of the ore and waste rock, acid generation would not be significant.

The Proposed Oro Cruz operations may impact groundwater by accidental leakage of solutions from the American Girl Canyon heap leach facility. A potential impact of mine waste material and exposed mineralized areas would be the leaching of constituents from these materials into surface water. The depths of open-pit mining in the proposed

Cross and Queen pits would generally be above the levels of groundwater encountered in Oro Cruz exploration holes. Groundwater inflows into the mine pits would be non-existent or limited to minor seeps.

For mitigation, processing facilities would continue to be regulated as a zero discharge site by the RWQCB requirements.

Oro Cruz tailings and spent ore were not predicted to leach metals or other constituents of concern for contamination of groundwater. The impact to groundwater quality from the leach pad was not predicted to be significant. Surface water quality data are unavailable due to the ephemeral nature of the streams. The impact of Oro Cruz operations on surface water quality was not predicted to be significant. The depths of open-pit mining in the proposed Cross and Queen pits would generally be above the levels of groundwater encountered in Oro Cruz exploration holes. Groundwater inflows into the mine pits were expected to be non-existent or limited to minor seeps.

No information was provided on discharges to groundwater or surface water.

6.3.4.2. ACTUAL WATER QUALITY CONDITIONS

The information on actual water quality conditions was based on a phone call with staff from the Regional Water Quality Control Board (RWQCB) in Palm Desert, California in September 2004. The American Girl Mine has completed mining operations, and the RWQCB rescinded their permit in 2004. The groundwater wells were abandoned and completely reclaimed after five years of post-closure monitoring (every six months). No water quality problems were encountered, but after shut down, one sampling had elevated copper concentrations in the groundwater. The RWQCB required monitoring for an additional five years, and no problems were encountered during this period. Groundwater monitoring was required for TDS, pH, copper, total cyanide, sulfate, arsenic, gold, silver, mercury, iron, nitrate and selenium.

6.3.4.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.9 provides a summary and comparison of potential, predicted and actual water quality information for the American Girl Mine. The accuracy of the predictions is discussed in this section.

To date, no groundwater, surface water or pit water quality impacts were observed.

Table 6.9. American Girl, CA, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings and Spent Ore	• Accidental leakage of solutions from the American Girl Canyon heap leach facility to groundwater	• Zero-discharge processing facilities	• No leaching of contaminants from spent ore to groundwater. Impact to groundwater from leach pad not significant	• None
Surface Water	Mine waste/ ore/exposed mineralized areas	•Leaching of constituents from mine waste/ exposed mineralized areas to surface water	• Zero-discharge processing facilities	• Impact to surface water quality not significant	• None
Pit Water	Open pit walls	• Groundwater inflows into the mine pits would be non-existent or limited to minor seeps.	• Zero-discharge processing facilities	• Groundwater table below bottom of pits	• None

6.3.5. CASTLE MOUNTAIN, CALIFORNIA

The Castle Mountain Mine, also known as the Viceroy Mine, is located in San Bernardino County and is owned by Viceroy Gold Corporation (75%) and MK Gold Company (25%). The mine operated from 1992 to 2001. Gold and silver ore are extracted from an open pit, and heap and vat leach processing were used. The mine is located on 3,645 acres of BLM land in the Needles District and 265 acres of private land; the number of disturbed acres is unknown. The bond amount is $1,605,000.

6.3.5.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA and CEQA were required for the new project to be permitted. A new project EIS/EIR was completed in 1990 (document not obtained after numerous attempts), and an expansion EIS was completed in 1997. The expansion included increasing the area of open pit, creating an overburden storage site and expanding the heap leach pad. There are no NPDES permits for the mine. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1998 EIS/EIR

The mine is in an arid desert setting. Precipitation in the New York Mountains in the northwest boundary of the valley exceeds 10 inches, while the valley floor receives ~8 inches. Streams within the basin are ephemeral, with the exception of Piute Spring, which flows perennially and is several miles from the mine site. Depth to groundwater is shallowest in the western recharge portion of the basin and becomes deeper toward the east. The general groundwater flow direction is toward the east-southeast. Depths in monitoring wells in the vicinity of the project area in 1990 ranged from ~360 - 750 feet.

Volcanic, metamorphic and igneous (granitic) rocks are in the project area. Recent alluvium has filled Lanfair Valley with 550-1000 ft of clay-rich Pleistocene age lacustrine deposits that are interbedded with Pleistocene lava flows. Static (ABA) and short-term leach tests (EPA Method 1312 - EP Toxicity test) were performed. Both the raw ore and leached ore show little to no potential to generate acid. Existing data indicate little potential for acid-producing conditions. Total sulfur was below detection in the overburden. In raw and leached ore, the NP/AP was 2.7 and 8.0 respectively. Soluble metals in the ore and overburden are non detectable for most metals. None of the results exceed California Soluble Threshold Limit Concentrations.

Due to low metal concentrations, the extremely dry site environment, and the net neutralizing potential of the ore and waste rock, the geochemistry of materials that would be mined was not expected to pose a threat to surface or groundwater quality. Because of the low soluble metals concentrations and the high NP:AP ratio of ore and overburden that would remain in the mine pit walls, it is expected that the quality of any water that could collect in the mine pits would be good. This water would be suitable for wildlife use.

The heap leach pads were planned to be lined, and sealed drainage/collection facilities would transport and contain the leaching solution. Leach pads dikes were proposed for confining and controlling drainage from the leach piles. At project completion, heap leach piles will be neutralized and rinsed and solution will be removed from storage facilities. Leakage detection/ monitoring system will be employed for the leach pads, emergency solution storage and storm water storage basins. If a pit lake forms, it will be monitored monthly for conformation to state and federal water quality standards. Should any pit lake constituent exceed a federal or state MCL, the pit will be backfilled above the high water level. Storage basins will be constructed with adequate freeboard to preclude entry of storm water into the system. No water quality impacts were expected after mitigation are in place.

No information was provided on discharges to groundwater or surface water.

6.3.5.2. ACTUAL WATER QUALITY CONDITIONS

Based on a phone call with staff of the Palm Desert Regional Water Quality Control Board in September 2004, the Castle Mountain, or Viceroy, Mine is in the process of closure and is still monitoring groundwater for TDS, total and free cyanide and arsenic. Groundwater at the site is approximately 600 ft deep, and there is no surface water near the mine. The Regional Board tests for heap leach impacts to groundwater from the pads and the ponds, with an emphasis on cyanide.

6.3.5.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.10 provides a summary and comparison of potential, predicted and actual water quality information for the Castle Mountain Mine.

Mitigation were used even though the potential for water quality impacts was low. There were no impacts to date.

Table 6.10. Castle Mountain, CA, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and surface water	Heap leach facility	• No threat to surface water or groundwater quality due to dry site environment and low potential to generate acid and metals	• Lined heap leach pad, leachate collection systems, leach pad dikes; rinsing and neutralization upon closure	• Same as potential	• None to date
Pit Water	Open Pit	• Good pit water quality due to low potential for acid generation and metals leaching; suitable for wildlife use.	• Monitoring; backfilling if standards exceeded	• Same as potential	• None to date

6.3.6. JAMESTOWN, CALIFORNIA

The Jamestown mine, owned by Sonora Mining Corporation, began operation in 1987 and closed in 1994. The primary commodity mined was gold from open pit mining and flotation processing, with vat leach processing operations conducted off-site. The mine is located on private lands. There is no current financial assurance for the mine.

6.3.6.1. WATER QUALITY SUMMARY

The County of Tuolumne has been the lead agency under the California Environmental Quality Act (CEQA) for the new project to be permitted, and an EIS/EIR was completed in 1983. Supplemental EIS/EIRs were conducted in 1986 and 1989 (not obtained), and an EIS/EIR was conducted in 1991 for mine expansion. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1983 EIS/EIR

According to the 1983 EIS/EIR, the Mother Lode ore zone is a quartz-rich and separated by a slate (phyllite) and serpentenite assemblages. A short-term leach test (WET or CAMWET test) was the only field or laboratory test mentioned in the EIS/EIR. Barium, arsenic and chromium were noted in the tailings leachate. Acid drainage potential was not specifically addressed. According to the EIS/EIR, the most important potential groundwater impact is the long-term migration of leachate generated from the tailings site. Dissolved constituents derived from the stockpiles may pass through the sedimentation ponds and eventually discharge to surface water. Accidental damage to the tailings pipeline could release chemical constituents (e.g., barium, arsenic, chromium) to surface water. Surface mine pits will be allowed to fill with water. The precise water quality of these ponds was not determined for the EIS/EIR but would presumably be of poorer quality than the pre-mining groundwater due to the effects of oxidation and evaporation.

According to the EIS/EIR, mitigation consisted of the tailings embankment being designed as a zero discharge system, but the potential for tailings water to seep from the pond into surface water was acknowledged. Surface water or groundwater quality impacts were not expected after mitigation are in place. The only impact that could not be mitigated would be lowered groundwater levels in the drawdown area near the pit.

1991 EIS/EIR

The proposed expansion included utilization of cyanide for leaching on site (not previously proposed or used). Short-term leach testing (CAMWET test) was performed on flotation tailings, thiourea tailings and representative rock and soil samples. Results indicated that the mine tailings will not contain contaminants that need to be controlled, and the overburden material was non-hazardous, non-toxic, and non-acid generating. According to the EIS/EIR, overall groundwater quality may be impacted to some degree by the quality of water in the abandoned pits. The impoundment water may contain concentrations of total dissolved solids higher than is currently present in the bedrock groundwater systems. Overburden storage areas could potentially impact the quality of surface waters, and the solution could potentially seep from the tailings facility into surface water.

According to the EIS/EIR, mitigation consisted of the zero discharge tailings embankment, the use of cyanide destruction processes, dilution of cyanide tailings with flotation tailings and monitoring. Erosion control structures for the tailings management facility were also mentioned. Potential impacts to groundwater and surface water were expected to be insignificant.

1985 Report of Waste Discharge

A 1985 Report of Waste Discharge (RWD) was obtained from the RWQCB. According to the report, hydrothermal solutions have mineralized ultrabasic intrusive rocks, sediments and volcanics, but the percentages of sulfides were low.

Waste Extraction Tests were performed on four samples: Composite head sample = ore from diamond drill core; Sample C = tailings and process water produced by thiourea leaching of the flotation concentrate; Sample D = tailings and process water produced by cyanide leaching; and Test #20 Tail = tailings from froth flotation testing without residue from treatment of the concentrate. A Potential Acidity with Peroxide test, described in EPA 670/274-070, pg 48-49, was also performed. Neutralization potential was tested using the procedure by Grube (pg 50-51 of the Report of Waste Discharge).

Each of the four samples was divided into two samples (A and B). For the composite head sample (ore), there were no exceedences of standards in the extract. For sample C (thiourea tailings), there were exceedences of arsenic (18 and 19 µg/l). Sample D (cyanide tailings) had exceedences of arsenic (15, 16 µg/l) and TDS (551, 550 mg/l). Sample Test #20 (froth flotation tailings) had one exceedence of arsenic (15µg/l). Generally all concentrations were low.

Acid base accounting tests were performed. The NP/AP ratios were 6.8 for the ore tailings, 2.8 for the thiourea tailings, and 3.1 for the cyanide tailings. The froth tailings generated no acid. Additional ore and waste rock samples (one ore and 5 waste rock) all had NP/AP values of between 3.5:1 and 47:1.

The Jamestown Mine (Harvard and Crystalline pits) was proposed to be operated as a closed system, with the exception of some seasonal surface runoff from the east side of the property that will be closely monitored.

6.3.6.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring data from 1988 to 2003 were obtained from the RWQCB and reviewed. No information was obtained on the number of surface water and groundwater monitoring locations, and no information was available on baseline water quality conditions or water quality violations.

The records show the following information on operational water quality:

- Exceedences of sulfate, nitrate and arsenic drinking water standards occurred in some groundwater monitoring wells. Downgradient of the waste rock and tailings management facilities, sulfate, nitrate, TDS and arsenic concentrations increased over time. Sulfate concentrations steadily increased (up to ~2,000 mg/l) since ~ 1990; nitrate concentrations increased (up to ~600 mg/l) from ~1990 to ~1997 and then decreased); total dissolved solids concentrations were as high as ~3,200 mg/l and are continuing to increase; and arsenic concentrations (up to 20 µg/l), may have peaked in the mid-1990s. For example, sulfate concentrations downgradient of the waste rock dump increased from 50 mg/l in January 1990 to 2,600 mg/l in May 2003, and increased in groundwater downgradient of the tailings facility from 63 mg/l in January 1988 to 2,000 mg/l in October 2003. TDS concentrations in a tailings area monitoring well increased from 310 mg/l in February 1988 to 3,200 mg/l in October 2003.
- Sulfate and nitrate concentrations exceeded drinking water standards in the Harvard Pit. Sulfate concentrations were continually increasing (up to ~1,200 mg/l), arsenic concentrations may have peaked in late 1990's (max. conc. = 1,600 µg/l l), and pH values decreased from ~8.5 (1987) to ~6.8 (2000). Sulfate concentrations were 10 mg/l in April 1988 (and then less than 200 mg/l for the remainder of 1988) and increased steadily to 1,200 mg/l in May 1999 and May 2003. Arsenic concentrations were ~10 µg/l in 1988 but increased to 1,600 µg/l in July 1991 and, with two exceptions, were >400 µg/l since 1995.

Before closure, Sonora Mining Company sold much of the land at the mine to Tuolumne County, and the county indemnified the mine, at the same time canceling a $3 million insurance policy for mine remediation. Since then, the RWQCB has sued the county for water quality violations related to the tailings impoundment and waste rock piles. The pit water at the site is considered groundwater, but there has been no official ruling yet on whether it is groundwater or surface water. The water level in the pit will be rising for the next 40 to 50 years. There were no notices of violation for pit water quality (RWQCB, October 2004 conversation).

6.3.6.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.11 provides a summary and comparison of potential, predicted and actual water quality information for the Jamestown mine. The accuracy of the predictions is discussed in this section.

<u>Observed Groundwater Quality Impacts from Tailings and Waste Rock</u>: The 1983 EIS/EIR indicated the potential for migration of tailings leachate to groundwater. However, no impacts to groundwater quality were predicted after mitigation were in place. The RWD noted that acid drainage potential was low but that there was potential for generation of contaminated leachate from the tailings. However, this information was not noted in the EIR/EIS.

The 1991 EIS/EIR also indicated no potential for acid drainage or other contaminants, although it does indicate that tailings and waste rock seepage with high TDS could impact groundwater and/or surface water. Laboratory test results indicated that the mine tailings will not contain contaminants that need to be controlled, and that the overburden material was non-hazardous, non-toxic and non-acid generating. Arsenic and TDS drinking water standards were slightly exceeded in the short-term leach tests performed on the tailings, but actual concentrations of arsenic, TDS, sulfate, and nitrate were substantially higher in groundwater.

Table 6.11. Jamestown, CA. Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings	• 1983 EIS/EIR: Migration of tailings leachate to groundwater and surface water 1991 EIS/EIR: No potential for acid drainage or other contaminant leaching. Seepage with high TDS could impact groundwater and/or surface water. Exceedences of As and TDS drinking water standards in short-term leach tests; NP:AP ratios 2.8 and 3.1.	• 1983 EIS/EIR and 1991 EIS/EIR: Facility design to prevent groundwater and surface water impacts. • Embankment design (zero discharge) • Compact tailings subsurface (no liner) • Grade and cap surfaces	• 1983 EIS/EIR: No impacts to surface water or groundwater quality after mitigation are in place • 1991 EIS/EIR: Potential impacts to groundwater and surface water are expected to be insignificant	WQ Monitoring: Groundwater affected by tailings and waste rock. Sulfate, nitrate, TDS and arsenic concentrations have increased significantly and exceed drinking water standards
	Waste Rock	• 1983 EIS/EIR: Migration of leachate to groundwater and surface water. Water quality from stockpiles would be of similar or lower quality than the pre-mining groundwater 1991 EIS/EIR: No potential for acid drainage or other contaminants. NP:AP ratios 3.5 to 47; no short-term leach testing on waste rock. Waste rock could affect surface water quality	• 1983 EIS/EIR: No mitigation identified • 1990 EIS/EIR: No mitigation identified		
Pit Water	Open Pit	• 1983 EIS/EIR: Similar or lower quality than premising groundwater due to oxidation and evaporation. Potential impacts to groundwater from water in pits. • 1991 EIS/EIR: Groundwater quality may be impacted by water in the abandoned pits	• 1983 EIS/EIR: No mitigation identified • 1990 EIS/EIR: No mitigation identified	• 1983 EIS/EIR: No impacts to surface water or groundwater quality after mitigation are in place • 1991 EIS/EIR: Potential impacts to groundwater and surface water are expected to be insignificant. No estimates of pit water quality.	Pit water sulfate concentrations have been continually increasing (up to ~1,200 mg/l), arsenic concentrations may have peaked in late 1990's (max. conc. = 1,600 $\mu g/l$), pH decreased from ~8.5 (1987) to ~6.8 (2000).

The EIS predicted that impacts to groundwater and surface water after mitigation are in place are expected to be insignificant. Therefore, the potential (pre-mitigation) water quality was a better measure of actual water quality than the predicted (post-mitigation) water quality impacts. Additionally, the 1991 EIS/EIR did not note the exceedences of sulfate, nitrate, TDS and arsenic in groundwater that were already evident in groundwater monitoring data by 1990. The test results were inaccurate, because contaminants have leaked from the tailings impoundment and the waste rock and impacted groundwater.

Observed Pit Water Quality Impacts: The 1983 EIS/EIR did indicate that pit lake water quality would be poorer than pre-mining groundwater quality. However, no details on the types of impacts (chemically) were presented. Therefore, predictions of pit water quality were correct generally, but neither the contaminants of concern nor the concentrations were estimated in the EIRs.

6.3.7. MCLAUGHLIN, CALIFORNIA

The McLaughlin Mine was owned by Homestake Mining Company and operated from 1985-2002. The primary commodity mined was gold from open pit mining and pressure oxidation of sulfide/refractory ore followed by vat leach cyanide processing operations. It disturbs 803 acres in the Ukiah District on BLM land. It has a current financial assurance amount of $12.2 million.

6.3.7.1. WATER QUALITY PREDICTIONS SUMMARY

The counties of Yolo, Napa and Sonoma were the lead agency under the CEQA for the new project to be permitted, and an EIS/EIR was completed in 1983. NEPA/CEQA was not required for the NPDES discharge permit. No subsequent NEPA or state equivalent environmental assessments were performed for the project. The following sections summarize the water quality predictions made in the NEPA document reviewed as well as information on actual water quality.

1983 EIS/EIR

Static and short term leach testing, paste pH, and an unidentified water quality model were presented as characterization and modeling approaches in the EIS/EIR. Copper, manganese and TDS were identified as the constituents of concern. They identified the potential for permanent degradation of groundwater quality; however, surface water quality impacts were predicted to be minimized with the implementation of mitigation measures. The pit water was predicted to be of poor quality.

According to the EIS/EIR, geochemical testing consisted of static (similar to NAG – using hydrogen peroxide), short-term leach (deionized water extraction test; California Waste Extraction Procedure), and paste pH tests. Modeling (type of model not specified) of impacts to surface water (Hunting Creek) quality was conducted. Constituents of concern identified included copper, manganese and total dissolved solids.

Ninety-two percent of the waste rock was determined to be either neutral or neutralizing. Comparison of the (tailings) extract analysis concentrations (from the WET test) with the health-based Soluble Threshold Limit Concentrations (STLCs) showed that the concentrations of copper exceeded the STLC; therefore, the tailings were considered hazardous. In addition to high copper values, the tailings extract also had lead, arsenic, silver and cyanide concentrations in excess of water quality standards.

According to the EIS, permanent degradation of groundwater quality was expected, due to tailings seepage. Potential impacts from waste rock to surface water included: (1) increased sedimentation from runoff, (2) increased total dissolved solids from leachate, and (3) increased heavy metal concentrations from acidic leachate. Water accumulated in the pit was expected to be of poor quality, with high concentrations of heavy metals and major ions including arsenic, cadmium, iron, lead, manganese, mercury, nickel, boron, sodium, chloride and sulfate.

Mitigation identified in the EIS included groundwater monitoring and underdrains for waste rock piles. Erosion/sedimentation controls would be used to protect surface water from waste rock impacts. Lime will be added to sediment ponds if acidic conditions are encountered during mining. Potentially acid generating rock will be surrounded by alkaline material during waste rock disposal. No mitigation for pit water or the tailings facility were identified.

The proposed tailings facility would allow 40 gpm of seepage to local groundwater underlying the reservoir. This impact would be long term, resulting in permanent degradation of the local groundwater and potentially of the shallow groundwater flowing toward surface water. Existing groundwater data in the tailings area showed poor quality water with long residence times and very low permeability. Therefore, although the proposed action and alternatives would lead to permanent degradation of localized groundwater, local water supplies would not be impacted, because the groundwater regime in the valley in which the tailings impoundment is located has not been found to be connected to a regional aquifer system, and the dam foundation would penetrate to less permeable material. There was predicted to be no impact to surface water quality under normal operation of the mill facilities.

Possible releases of TDS could occur from the waste rock dump but were planned to be collected in the underdrains, the diversion ditches, or in the sediment impoundment. Modeling indicated that arsenic, nickel, zinc, silver, iron, and copper concentrations would be lower than drinking water standards in surface water. Manganese was predicted to slightly exceed its standard.

The quality of water accumulated in the pit was expected to be of poor quality, with high concentrations of metalloids, heavy metals and major ions, including arsenic, cadmium, iron, lead, manganese, mercury, nickel, boron, sodium, chloride and sulfate. Alkaline-producing materials in the rocks would likely produce alkaline pH conditions in the mine pit water and would tend to reduce metals leached from the rocks. Pit water would not reach surface streams, and no impacts on the quality of surface water were anticipated.

6.3.7.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring data were obtained from the RWQCB in Sacramento for 1982 to 2004 and included the following:

- Baseline water quality data from 1982 – 1986 indicate that groundwater hydraulic conductivity is low and existing water quality poor and groundwater is considered to be unusable. The mine obtained an exclusion for meeting groundwater standards at the site, with groundwater standards set at no increase over background.
- Groundwater monitoring wells downgradient of the tailings impoundment showed increases and exceedences of TDS, chloride, nitrate, and sulfate from ~1984 to ~1992, with increases of copper and other metals during the same period.
- Groundwater monitoring wells downgradient of the waste rock dumps show increasing concentrations of sulfate (in excess of SDWA standards), boron, TDS, calcium, iron, manganese and other constituents from ~1985 to ~1998. Zinc concentrations increased after 1998.
- Surface monitoring locations downstream of the mine show exceedences of sulfate and occasionally large exceedences of arsenic, chromium, copper, lead, manganese mercury, lead, iron and zinc.
- The open pit also receives pump-back water from the waste rock dumps, so water chemistry may also reflect waste rock drainage/leachate. Pit water exceeds secondary drinking water standards for pH (low), TDS, chloride, sulfate, iron and manganese. If pit water discharges to surface water, the elevated concentrations of copper, nickel, and zinc could cause exceedences of standards for the protection of aquatic life.
- No violations were noted. According to the RWQCB, if concentrations chronically exceed standards, enforcement actions are issued. However, apparently due to the regulatory exclusion for groundwater at the site no enforcement actions were taken by the RWQCB despite evidence that groundwater has been chronically degraded below the tailings impoundment and waste rock storage areas. Similarly, no enforcement actions were taken by the RWQCB, despite apparent evidence of chronic degradation of surface water.

6.3.7.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.12 provides a summary and comparison of potential, predicted and actual water quality information for the McLaughlin mine. The accuracy of the predictions is discussed in this section.

Table 6.12. McLaughlin, CA, Potential, Predicted and Actual Impacts
(all information from 1983 EIR/EIS unless otherwise noted; actual impacts from water quality monitoring data)

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings	• Permanent degradation of groundwater is expected, due to tailings seepage	• Monitoring only	• Permanent degradation of local groundwater from tailings, but no impact outside the existing poor quality confined aquifer	• Downgradient wells show increases and exceedences of TDS, chloride, nitrate, and sulfate from ~1984 to ~1992, with increases of copper, and other metals
	Waste Rock	• Possible release of TDS could occur from waste rock dump	• Leachate will be collected in the underdrains, the diversion ditches, or in the sediment impoundment. • Segregation and blending of PAG waste rock.	• Groundwater will not be impacted outside the existing poor quality confined aquifer	• Downgradient wells show increasing concentrations of sulfate (in excess of SDWA standards), boron, TDS, calcium, iron, manganese, and other constituents from ~1985 to ~1998. Zinc concentrations increased after 1998
Surface Water	Tailings	• No impact to surface water quality	• No mitigation identified	• No impact to surface water quality	• Downstream surface monitoring locations show exceedences of sulfate, and occasionally large exceedences of arsenic, chromium, copper, lead, manganese, mercury, iron and zinc
	Waste Rock	• Surface water quality impacts may potentially occur from waste rock o increased sediment o increased total dissolved solids o increased heavy metal concentration	• Lime will be added to sediment ponds if acidic conditions develop • Segregation and blending of PAG waste rock	• Manganese was predicted to slightly exceed its standard	
Pit Water	Open Pit	• Pit water is expected to be of poor quality	• Alkaline pH conditions in the mine pit would tend to reduce metals leached	• Pit water not expected to reach surface streams	Pit water exceeds secondary drinking water standards for pH (low), TDS, chloride, sulfate, iron and manganese

<u>Degradation of Local Groundwater from Tailings and Waste Rock Seepage</u>: The 1983 EIS/EIR identified the potential for permanent degradation of local groundwater from tailings seepage. Release of TDS from waste rock was predicted, but mitigation measures (underdrains, diversion ditches, segregation of PAG rock, lime addition to waste rock runoff) were expected to avoid impacts to groundwater. However, wells downgradient of waste rock show elevated sulfate (up to 5,000 mg/l), boron, TDS, iron, manganese and zinc (up to 1.7 mg/l) concentrations. Therefore, groundwater impacts from tailings were accurately predicted, but predictions for groundwater impacts from waste rock were inaccurate.

Surface Water Impacts: Potential surface water quality impacts from tailings were not expected; however, potential impacts from waste rock were recognized and modeled. Modeled arsenic, nickel, zinc, silver, iron and copper concentrations were predicted to be lower and manganese higher than drinking water standards in Hunting Creek. The modeling results were correct for zinc, silver, manganese and copper, which did not exceed standards but were incorrect for arsenic, nickel and iron, which did exceed standards.

Pit Water Quality: Pit water quality was expected to be poor (with high concentrations of arsenic, cadmium, iron, lead, manganese, mercury, nickel, boron, and sulfate, but alkaline conditions were expected to reduce metal concentrations. The pit water is of poor quality, as predicted. There are elevated concentrations of iron, manganese, nickel, boron, sodium, chloride and sulfate, as predicted, but there are not high concentrations of arsenic, cadmium or lead at this time. The pH of the pit water is 5.08, which is acidic rather than alkaline, so the prediction that the pit water will have an alkaline pH is inaccurate. Pit water quality exceeds drinking water drinking water standards for pH (low), TDS, sulfate, manganese, nickel and boron.

6.3.8. MESQUITE, CALIFORNIA

The Mesquite Mine is owned by Newmont Mining Company and is an open pit, heap leach gold and silver operation. Production started in 1985, and the mine is still in operation. The mine disturbs 3,655 acres of BLM land in the El Centro District, and has a financial assurance amount (last updated in 1998) of $3,048,081.

6.3.8.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA and CEQA were required for the new project to be permitted. A new project EIS was completed in 1984, and two expansion EISs were conducted in 1987 and 2000. The new project EIS (1984) and the 2000/2002 (draft/final) expansion EIS were obtained for this report. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1984 EIS

From a rain gauge 14 miles away, annual precipitation ranged from 1.17 to7.42 inches. Annual rainfall in the Amos basin probably ranges from 3 inches on the valley floor to 5.5 inches in the higher mountains. Mean annual pan evaporation is 137 inches, mean annual lake evaporation is 96 inches. The Coachella Canal, approximately 15 miles southwest of the project area, is the closest perennial surface water feature. Drainages on the site flow only during infrequent thunderstorms. Groundwater occurs in alluvial deposits, and, to a limited extent, in fractures and joint systems in bedrock in the Chocolate Mountains. Average depth to groundwater near the proposed Mesquite mine is 200 feet below ground surface. Depth to groundwater becomes as shallow as 145 feet just south of highway 78.

Alluvium covers a majority of the site. Older rocks include Miocene/Oligocene non-marine silts, sand, angular gravel, with a considerable amount of gypsum, and Mesozoic and Precambrian igneous and metamorphic rocks in the northern part of the site. Static acid-base potential tests were performed on overburden and leached ore. Both overburden and leached ore residue have sufficient neutralizing capacity to prevent any formation of acidic leachate.

Water quality impact potential: Background groundwater quality in the region had exceedences of fluoride in most wells and chloride, sulfate, iron, manganese and arsenic in alluvial wells. Bedrock wells exceeded for iron, manganese, arsenic and mercury. The only potential significant environmental impact to groundwater would be from percolated surface waters containing chemicals used in ore processing, accidental fuel spillage, spillage of reagents or chemicals, breakage of solution pipelines or leachate from waste dumps. Low soil moisture and depth to groundwater present a secondary defense against contamination. Surface water in the Imperial Valley typically has high TDS values, around 990 mg/l. Surface water quality in the project area could be affected by the presence of suspended solids in runoff, hazardous materials accumulated in the processing plant area or by any accidental escape of leach solution from the processing system. There will most likely be pit lakes because pit bottoms will be 400-500 ft deep.

Proposed mitigation include: impermeable liners for leach pads; immediate application of calcium hypochlorite to any spilled/released cyanide on exposed soil; containment area around reagent building; sumps in process building to collect spilled materials; collection and storage for runoff from the heap leach facility; rinsing of heap leach pads upon completion of the leaching; and impervious barriers under areas exposed to toxic chemicals.

Predicted water quality impacts: As a result of implementing the proposed project design and all solution containment measures, no significant adverse impact on groundwater quality is expected. The proposed project design includes measures to prevent any adverse impacts on surface water quality, including the prevention of contamination from the use of dilute cyanide leach solution. No information was provided on discharges to groundwater or surface water.

2000/2002 EIS

Annual precipitation is three inches/ear, and evaporation is ~80 inches/year. The closest perennial surface water feature is the Coachella Canal, located approximately 15 miles southwest of the site. The groundwater flow direction is generally from northeast to southwest, following the surface contours. Prior to mining, groundwater depths ranged from about 200 to 300 feet deep.

Gold ore occurs in gneiss and granitic basement rock in essentially free or native forms. It is concentrated in microfractures in minute sizes and amounts. Minor amounts of silver ore are found disseminated in microfractures of gneiss and granitic basement rock. Static acid-base accounting, whole rock analysis for metals, and 20-week kinetic tests were performed. From whole rock analysis, arsenic, selenium, silver, bismuth and thallium were identified as potential constituents of concern. Rock types encountered in the Rainbow and north half sections were typically net neutralizing. The kinetic tests were inoculated with *Thiobacillus ferrooxidans* and showed no acid generation or any indication that acid would form. The kinetic tests indicated that even the most sulfidic members of the hornblende biotite gneiss and mafic gneiss rock units are not likely to generate acid. Soluble metals concentrations in the overburden/interburden were generally low. A hydrologic/hydraulic evaluation of runoff was conducted using the runoff model HEC-1. Pit water quantity and quality modeling was conducted by Baker Consultants.

Ore processing operations could leak or spill processing fluids if they are not properly designed, constructed and operated. Petroleum products could impact groundwater if a substantial leak were to occur. Infiltrating precipitation could carry soluble constituents from the overburden/interburden to groundwater. Increased runoff could occur from road surfaces during infrequent large storms, but roads cover only a small fraction of the site. The potential exists for minor hydrocarbon leaks/spills from equipment. Water quality in the existing pit lake is generally alkaline (pH 8.3 - 8.9), slightly to moderately saline (total alkalinity 258 - 334 mg/l of $CaCO_3$, TDS 1,400 - 3,600 mg/l) and low in dissolved trace metals. Initially, the pit water chemistry will be similar to the existing pit water, with TDS in the 1,500-400 mg/l range. At equilibrium, TDS is expected to reach 5,000-10,000 mg/l. Long term pit chemistry will be the same as the existing pits.

Proposed mitigation for the expansion include: heap leach pad liner and leak detection system; monitoring; storage of bulk petroleum products above ground in designated areas with secondary containment and leak detection. Best Management Practices will minimize stormwater-related pollution and include monitoring and inspection protocols to gauge their effectiveness. Ore processing facilities will have run-on controls and will be operated in a manner that protects against release of process fluids or other constituents that may adversely affect surface water quality.

Groundwater quality was evaluated over five years for pH, specific conductance, temperature, total dissolved solids, arsenic, copper, iron, sulfate and nitrate/nitrite. None of the parameters showed trends of adverse change in water quality. There are no known groundwater quality impacts from the 15 years of activity that have occurred at the Mesquite Mine to date. Modeling indicates that for the out-of-pit configuration, groundwater would not flow through any of the mine pits, so the build up of dissolved constituents in the pit lakes will not affect water quality away from the mine pits. With petroleum containment and monitoring in place, fuels and oil use at the site are not expected to impact groundwater quality. Because soluble metals concentrations in waste rock are generally low and the material is not acid generating, and because of the low annual precipitation, waste rock would not have a significant impact on groundwater quality. With heap leach pad operation requirements in place, significant effects to surface water quality are not expected. The likelihood of spills is small, and they would be easily removed. Long term pit chemistry is expected to be the same as the existing pits. No information was provided on discharges to groundwater or surface water.

6.3.8.2. ACTUAL WATER QUALITY CONDITIONS

The information on actual water quality conditions is based on a phone call with the RWQCB in Palm Desert, California, in September 2004. The Mesquite Mine is still conducting leaching operations but is otherwise shut down. There was one unreported spill in early 2003/late 2002, and a violation was written by the RWQCB. However, this was a very minor spill. Quarterly reporting is required for TDS, total and free cyanide, pH, sulfate, arsenic, gold, silver, copper iron, and nitrate. No major problems, for example with cyanide, have occurred.

6.3.8.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.13 summarizes potential, predicted and actual impacts for the Mesquite Mine. A spill did occur in 2002/2003. The potential for spills was recognized in both the 1984 and 2002 EISs, but because of mitigation measures, they were expected to be cleaned up rapidly and not affect groundwater or surface water. To date, this prediction has been true.

Table 6.13. Mesquite, CA, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	• Heap leach facility • Waste rock	• Ore processing fluids, fuel or chemical spills, pipeline breaks, waste rock leachate (1984) • Leaks or spills of ore solution, petroleum leaks, leachate from waste rock (2002)	• Leach pad liners, calcium hypochlorite applied to cyanide spills, rinse pads after mining (1984) • Heap leach pad liner/leak detection, monitoring, storage of petroleum products in areas with secondary containment, leak monitoring (2002)	• No impact to groundwater (1984) • No impacted predicted because existing groundwater quality unchanged and fuels/oil containment/monitoring. Waste rock would no have significant impact. (2002)	• Spill occurred, but no impacts to groundwater occurred.
Surface Water	• Heap leach facility	• Erosion of soils, processing plant materials, ore solution leachate (1984) • Runoff from roads, fuel spills	• Reagent containment and sumps, heap leach runoff controls (1984) • Stormwater BMPs, monitoring, heap leach run-on controls (2002)	• No impact to surface water quality (1984) • No significant surface water quality effects expected from heap leach pad or spills (2002	• Spill occurred, but no impacts to surface water occurred.
Pit Water	• Open pit	• Pit lakes will exist (1984) • Long-term pit chemistry same as existing pits (2002)	• None	• No information (1984) • Long-term pit chemistry expected to be same as existing pits.	• None

6.3.9. ROYAL MOUNTAIN KING, CALIFORNIA

The Royal Mountain King Mine is owned by Meridian Gold, Inc. and was in operation from 1990 to 1995. The primary commodity mined was gold from open pit mining and vat leach processing operations. It disturbed 650 acres on private land. It has a current financial assurance amount of $3.3 million.

6.3.9.1. WATER QUALITY PREDICTIONS SUMMARY

El Dorado County was the lead agency under CEQA for the new project to be permitted, and an EIS/EIR was completed in 1987. NEPA/CEQA was not required for the NPDES discharge permit. The following sections summarize the water quality predictions made in the documents reviewed.

1987 EIS/EIR

The EIS/EIR contained very little information on geochemical characterization tests (only static acid-base accounting tests were performed) and did not identify any particular constituents of concern. Based on static acid-base accounting test results, the EIS/EIR concluded that there was no net acid forming potential associated with the overburden materials. No information was provided on contaminant leaching potential. The EIS/EIR stated that the waste management units will contain chemicals and reagents that have the potential to contaminate the groundwater system. No information was provided on mitigation, with the exception of stormwater management approaches.

Additional Information

1988 Geochemical Characterization Testing by Donald R. Baker

Geochemical characterization testing consisted of total digestions of tailings and waste rock samples (results were compared to Total Threshold Limit Concentrations (TTLC)), WET tests on waste rock (results were compared to Soluble Threshold Limit Concentrations (STLC)), and a Deionized Water Extraction test on waste rock. Total digestion leachate values for tailings were elevated for antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, selenium, silver, vanadium and zinc (>10 to 100 times MCL/SMCL values). Total digestion and WET test values for waste rock leachate were elevated for antimony, arsenic, beryllium (total digestion only), cadmium (total digestion only), chromium, cobalt, copper, lead, mercury (total digestion only), nickel, silver (total digestion only), vanadium (total digestion only) and zinc. Deionized water extract concentrations for waste rock were elevated for arsenic.

1987 Report of Waste Discharge

According to the report, three different types of ore will be mined in the project. The Skyrocket ore body, which comprises roughly 59% of the total reserves, is a refractory (unoxidized) carbonaceous deposit. Mountain King, which comprises 30% of ore reserves, is predominantly unoxidized. Gold Knoll, the remaining 11% of reserves, is a mix of oxidized and unoxidized ore.

There will be three sources of solid waste generated on the property: overburden; flotation tailings; and heap leach concentrate residues. Each type of waste was subjected to: acid-base accounting (hot hydrogen peroxide oxidation); total metal content; short-term leach (WET, DI water extract); sulfuric-acid extractable metal concentration for samples with acid-forming potential; and bioassay studies on all wastes except overburden. The testing results showed the contaminant potential to be high for all materials.

Overburden. Deionized water extractions on waste rock material showed several exceedences of drinking water standards. Arsenic concentrations in the extract exceeded drinking water standards (10 µg/l) by over 10 times, and selenium concentrations in leachate from one sample were elevated but did not exceed the drinking water standard. Total chromium concentrations exceeded the drinking water standard by almost two times. For the WET test results, leachate concentrations in samples from all four types of overburden exceeded the drinking water standard for arsenic by factors of 2 to 26, and chromium concentrations also exceeded drinking water standards in all four waste rock types ranging from a factor of 1.5 to 3. Nickel concentrations also exceeded drinking water standards in all four samples, with concentrations ranging between 4 to 7 times the remanded standard of 100 µg/l.

Flotation Tailings. WET test leachates for all four tailings lithologies (one from each pit, as well as a composite) showed drinking water exceedences for arsenic, barium, total chromium, lead, and nickel; the detection limit for mercury in the WET leachate was too high to conduct comparisons to standards. There was also a single exceedence (from the Mountain King pit) for selenium. In the deionized water extraction, there was one drinking water exceedence for selenium in a leachate sample from the Mountain King pit, and one exceedence of arsenic, also from the Mountain King pit. Arsenic levels in the DI extraction leachate were equal to the drinking water standard in the Gold Knoll pit sample. Arsenic concentrations in the DI extraction leachate exceeded the drinking water standard in all four floatation tailings samples by a factor of 2 to 3. Lead concentrations in the DI leachate were elevated but did not exceed the drinking water standard. Nickel concentrations exceeded the remanded drinking water standards in DI leachate from the Mountain King pit sample.

Leached Concentrates (Heap Leach Ore). Arsenic concentrations in the heap leach concentrates were high enough to classify this material as hazardous waste, according to the TTLC. In the deionized water extraction of the leached concentrates, antimony concentrations exceeded the drinking water standard by a factor of more than 10 in all four samples (each pit, as well as a composite sample). Arsenic concentrations exceeded the new standard in all four samples by factors of fewer than 2 to almost 3. The detection limit for lead exceeded current standards. Mercury concentrations exceeded the standard in the Gold Knoll pit sample. Nickel concentrations exceeded the remanded drinking water standard by a factor of almost two in the Sky Rocket sample and was at the standard in the composite sample. In addition, results from the extraction procedure utilizing citric acid (WET test) showed elevated concentrations of antimony, arsenic, lead and nickel from all samples. The lead levels in the Mountain King pit samples were high enough compared to the STLC to merit classifying the heap leach concentrates as a hazardous waste. Extractions using H_2SO_4 produced results similar to the DI water extraction. The leached transport solution exceeded, by a factor of over one hundred, the drinking water standards for arsenic, copper, cyanide and mercury, TDS, and nickel concentrations exceeded drinking water standards in the transport solution by 10 times or more. Lead, silver, sulfate and zinc concentrations in the leach transport solution exceeded drinking water standards by one to 10 times. Detection limits for cadmium, chromium, silver and thallium for leach transport solutions were higher than their respective water quality standards.

Acid Drainage Potential. All overburden lithologies and flotation tailings samples had excess neutralization potential. NP:AP ratios were approximately 40:1 or higher, indicating that acid generation was unlikely. However, acid generation potential was high in the concentrates from the heap leaching circuit, with NP:AP ratios ranging from 1:3 to 1:12.

According to the report, the tailings impoundment will not require an engineered lining. Both the solids and the liquid in the slurry were tested extensively and do not present any potential for having an adverse impact on the environment. In addition, the rocks underlying the tailings impoundment have low permeabilities.

6.3.9.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring data were obtained from the RWQCB in Sacramento for 1987 to 2004 and included the following:

- Tailings wells showed exceedences of drinking water standards for chloride, nitrate, nickel, selenium, sulfate, TDS and manganese. Heap leach concentrate area wells had exceedences of drinking water standards for antimony, arsenic, chromium, manganese, copper, nickel, nitrate, selenium, sulfate, TDS, and total and WAD cyanide. Waste rock wells showed exceedences of drinking water standards for nitrate, TDS, sulfate, arsenic, chloride and selenium.

- Surface water monitoring showed exceedences of drinking water standards for nitrate, sulfate, TDS and arsenic.
- Pit water monitoring shows exceedences of sulfate and TDS SMCL values in North Pit; exceedences of arsenic, sulfate, TDS, and chloride drinking water standards in Skyrocket Pit.
- The mine area has been subject to historic mining, so background water quality (pre-historic mining) is difficult to determine. There are some artesian salt springs in the marine deposits, but not all groundwater is salty. Skyrocket Pit outlet flows to Littlejohns Creek. The mine claims that elevated groundwater concentrations are background levels. Some of the groundwater is very salty, but the chemical signature from the waste rock piles is still apparent. The RWQCB proved, using Piper diagrams, that the groundwater had changed over time as a result of mining activity (RWQCB interview, 10/15/04).
- There were 29 violations issued to the mine from the RWQCB from January 1993 to August 2004; between nine and 12 of them were related to water quality or quantity problems, and the remainder were related to inadequacies in reporting and other non-water quality issues. The State Water Control Board, not the RWQCB, vacated the 2003 cease and desist order, agreeing with the mine that it was too complex, and the State Board was not sure the mine could comply with the order. If the order had been kept, the mine would be in violation all the time. The RWQCB feels that the financial assurance is too low because it does not include foreseeable future releases.
- Local public interest groups have sued Royal Mountain King for discharges to Littlejohns Creek (from Skyrocket Pit) and for the presence of elevated arsenic, ammonia and cyanide in groundwater. The lawsuit requests a cease and desist order and containment.
- Meridian Gold received the California Mining Association Reclamation Award in 1994.

6.3.9.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.14 provides a summary and comparison of potential, predicted and actual water quality information for the Royal Mountain King mine. The accuracy of the predictions is discussed in this section.

Groundwater Impacts from Tailings: The 1987 EIS/EIR did not address potential impacts from tailings but did state generally that waste management units will contain chemicals and reagents that have the potential to contaminate the groundwater system. The 1987 Report of Waste Discharge (RWD) found that tailings do not have the potential for impacts, that low permeability material below the impoundment was sufficient mitigation, and therefore no engineered lining was required. However, water quality monitoring results from wells downgradient of the tailings impoundment showed exceedences of drinking water standards for sulfate, chloride, nitrate, nickel, selenium, TDS and manganese. Therefore, the potential impact information for tailings presented in the EIR was accurate, but the predictions based on the low permeability material were inaccurate and resulted in inadequate mitigation measures being taken at the site.

Groundwater Impacts from Waste Rock: The 1987 EIS/EIR determined, based on the results of static testing, that there was no net acid forming potential associated with waste rock. The RWD found that the waste rock was not considered hazardous. Short-term leach test leachate exceeded drinking water standards for arsenic, selenium, chromium and nickel. Water quality monitoring results from wells downgradient of waste rock showed exceedences of drinking water standards for nitrate, total dissolved solids, sulfate, arsenic (up to 1,400 μg/l), chloride and selenium. Therefore, predictions for groundwater impacts from waste rock were accurate for arsenic and selenium, but not for chromium and nickel. In addition, short-term leach testing results did not predict the observed exceedences of nitrate, TDS, sulfate and chloride.

Arsenic concentrations were increasing steadily from 1987 to 2004. Nitrate, TDS, sulfate, chloride and selenium concentrations were not predicted to be elevated but were (if they were monitored). The other constituents that were predicted to be elevated in waste rock leachate are not elevated in groundwater downgradient of the waste rock storage areas at this time. Pit water (Skyrocket Pit) has elevated concentrations of antimony, arsenic, nickel, sulfate and TDS. All of these except sulfate and TDS were predicted based on short-term leach results for waste rock.

Groundwater Impacts from Heap Leach Facility: The 1987 EIS/EIR stated generally that waste management units will contain chemicals and reagents that have the potential to contaminate the groundwater system. The RWD found

Table 6.14. Royal Mountain King, CA, Potential, Predicted and Actual Impacts
(all information from the 1987 EIR/EIS unless otherwise stated; actual impacts information from water quality monitoring data)

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings	• Waste management units will contain chemicals and reagents that have the potential to contaminate the groundwater system.1987 RWD: Tailings do not present any potential for adverse impact to the environment, underlying rocks have low permeability.	• RWD: Tailings impoundment will not require an engineered liner	• No information.	Tailings wells show exceedences of drinking water standards for chloride, nitrate, nickel, selenium, sulfate, TDS, manganese.
	Waste Rock	• No net acid forming potential associated with the overburden materials	• Only stormwater controls		• Waste rock wells show exceedences of drinking water standards for nitrate, TDS, sulfate, arsenic, chloride, selenium.
	Heap Leach Concentrate	• Waste management units will contain chemicals and reagents that have the potential to contaminate the groundwater system. RWD: Short-term leach tests solution would be elevated in Sb, As, Cu, CN, Pb, Hg, SO4, TDS, Zn.	• None identified. RWD: liner required.		• Heap leach area wells show exceedences of drinking water standards for antimony, arsenic, chromium, manganese, copper, nickel, nitrate, selenium, sulfate, TDS, total and WAD cyanide.

that arsenic and lead concentrations in the heap leach concentrates were high enough to classify them as hazardous waste; therefore, a liner was required. Short-term leach tests predicted that heap leach concentrate solution would be elevated in antimony, arsenic, copper, cyanide, lead, mercury, nickel, sulfate, TDS and zinc. Groundwater downgradient of the leach pad facility showed exceedences of drinking water standards for antimony, arsenic, chromium, manganese, copper, nickel, nitrate, selenium, sulfate, TDS, total and WAD cyanide. Of these, antimony, arsenic, copper, nickel, sulfate, TDS and cyanide were predicted to be elevated. Chromium, manganese, nitrate and selenium concentrations were not predicted to be elevated or were not evaluated, but they were elevated in wells downgradient of the heap leach facility. Therefore, the potential water quality concerns were accurate (in particular, arsenic was released from the lead pad materials), but the designated mitigation (liner) did not prevent the contamination of downgradient groundwater.

6.3.10. GROUSE CREEK, IDAHO

The Sunbeam Mine, owned by Sunbeam Mining Company, began operations in 1984. The Hecla Mining Company began mining the Grouse Creek and Sunbeam deposits in 1994 and operated until its closure in 1997. The primary commodities mined were gold with some silver from open pit mining, with heap leach and vat leach processing. It disturbs 524 acres on private land and Challis National Forest lands in Forest Service Region 4. It has a financial assurance amount of $7,038,945.

6.3.10.1. WATER QUALITY PREDICTIONS SUMMARY

The Challis National Forest has been the lead agency for all NEPA actions at the Ground Creek Mine. NEPA was required for the new project to be permitted, and an EIS was completed in 1984. The EIS was also utilized by the EPA in issuing the NPDES discharge permit. A subsequent EIS for mine expansion was completed in 1992. The following sections summarize the water quality information and predictions made in the NEPA documents reviewed.

1984 EIS

The 1984 EIS describes the deposit as a gold and silver ore containing pyrite and iron oxides. Acid drainage was observed from the Sunnyside Mine adit (pH range of 3.3 to 3.9) on the study site, indicating the presence of acid drainage. However, the EIS stated that the potential for generating significant acid drainage from mine or waste dumps is minimal, based on the fact that very little sulfide material is available within the ore body and that “weather tests” indicated that the pH of the drainage of mine-run samples is stable. The acid drainage that has been reported from the abandoned Sunbeam Mine portal (pH 3.2) may be a result of an isolated sulfide-bearing stratum within the mine area itself that is exposed to localized oxidation conditions due to variation in the water table within the mine area. The EIS stated that the proposed Grouse Creek open pit will not be subject to the same conditions that can cause the formation of acid drainage. Mitigation identified included surface water controls and surface water and groundwater monitoring. Cyanide was identified as a constituent of concern.

1992 SEIS

The 1992 Supplemental EIS identified the gold and silver ore deposit as containing gold, native silver, electrum, metal sulfides, including pyrite, and iron oxides. Results of geochemical testing (including sulfur analysis, static ABA and short term leach tests) indicated that moderate acid drainage was expected. Metals, metalloids, and other contaminants (nitrate and cyanide) were identified as constituents of concern; however, EP toxicity analysis of waste rock samples indicated the potential for heavy metal concentrations in leachate to be “relatively low,” with lead being the only metal expected to exceed drinking water MCLs, as long as the water maintained a low to moderate acidity. The potential for significant groundwater degradation was determined to be minimal, and the potential for cyanide entering groundwater in sufficient quantities to do real harm was described as very minimal, but the potential does exist.

Source controls for groundwater capture and treatment and storm water controls were required during operations. There is a potential for some drainage from the Grouse Creek pit to occur post-reclamation, but the water is not expected to be acidic because of the buffering capacity of the carbonate-rich rocks.

6.3.10.2. ACTUAL WATER QUALITY CONDITIONS

Hecla experienced financial difficulties at the same time that water quality issues became noticeable. In 2000 the Grouse Creek Mine was declared a Forest Service Superfund site, and in 2002 an Engineering Evaluation/Cost

Analysis (EECA) for Non-time Critical Removal Action was performed at the Grouse Creek Mine Site. The following information was taken from the EECA.

Hecla Mining Company has been monitoring water quality since 1987. In 1995 cyanide was detected in both surface water and groundwater monitoring stations. Cyanide detection in wells below the South Embankment indicated that contaminated water was moving through the underlying materials below the tailings impoundment. Cyanide was periodically detected in Jordan Creek below the constructed wetlands. Since 1999, cyanide (total and WAD) concentrations have decreased in Jordan Creek. Since 2001, cyanide (WAD) concentrations have mostly been below detection limits (0.002 mg/l).

Chemicals of Potential Concern identified in tailings pore water included aluminum, copper, arsenic, selenium, silver, zinc, cyanide, ammonia and mercury. Constituents that exceeded acute water quality criteria for protection of aquatic life included aluminum, copper, arsenic, selenium, silver, zinc and cyanide. Sampling data showed trends toward generally improving tailings impoundment water quality when the EE/CA was written. WAD cyanide concentrations were decreasing and were predicted to decline to less than 0.0025 mg/l by April 2002. Ammonia concentrations were declining steadily in tailings impoundment water and were predicted to be below 25 mg/l in 2003 and below 20 mg/l in 2004. Silver concentrations were declining, and concentrations at most sampling sites currently are below the detection limit (0.0005 mg/l). Copper concentrations have declined to an average of 0.04 mg/l since Fall 2000, and mercury concentrations were below the detection limit of 0.0002 mg/l. Total nitrate concentrations were increasing steadily, possibly due to metabolism of ammonia by microbial biomass.

Some contamination of groundwater is still evident at the site. However, since 2001, all contaminants of concern entering the Yankee Fork receiving water were below detection limits. Detectable cyanide (WAD and total) concentrations were last measured in Jordan Creek in June 2000.

6.3.10.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.15 provides a summary and comparison of potential, predicted and actual water quality information for the Grouse Creek Mine. The accuracy of the EIS water quality predictions is discussed in this section.

Table 6.15 Grouse Creek, ID, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings and Waste Rock	• 1984 EIS: acid drainage observed but geochemical tests indicated minimal acid drainage potential • 1992 SEIS: Moderate acid drainage potential; low risk of significant groundwater contamination but potential impact to surface water from tailings	• 1984 EIS: stormwater controls and water monitoring • 1992 SEIS: stormwater controls and groundwater capture and treatment during operations; reclamation with buffering rock; composite liner system for tailings impoundment; French drains under waste rock dumps	• 1984 EIS: no impacts to water quality • 1992 SEIS: no impacts to water quality; adverse water quality effects from impoundment leakage unlikely due to underdrain and collection system	• EE/CA: tailings impoundment leakage into groundwater resulted in CN in groundwater and surface water. Tailings pore water exceeds standards for aluminum, copper, arsenic, selenium, silver, zinc and cyanide.

Cyanide in Groundwater and Surface Water. Cyanide was identified as a constituent of concern in both the 1984 and the 1992 EISs. The potential for contamination of groundwater by cyanide was recognized in the 1992 SEIS, but the actual potential was described as very minimal. Short-term leach tests performed for the 1992 SEIS indicated metal concentrations in leachate would be low with only lead predicted to exceed drinking water MCL's as long as the water maintained a low to moderate acidity. The EE/CA showed that the tailings liner failed to contain the tailings solutions and the underlying French drain system did not capture all tailings leakage, resulting in contamination of groundwater and surface water with cyanide and other contaminants. Although the potential for cyanide contamination of groundwater and surface water was noted in the 1992 SEIS, adverse water quality effects from impoundment leakage was wrongly thought to be unlikely due to mitigation such as the underdrain and collection system. Therefore, the observed impact to groundwater and surface water from tailings leakage was not predicted.

6.3.11. THOMPSON CREEK, IDAHO

The Thompson Creek Mine, owned by Thompson Creek Mining Company, has been in operation since 1983. The primary commodity mined is molybdenum from open pit mining and flotation processing operations. It disturbs 2,100 acres on Salmon-Challis National Forest lands in U.S. Forest Service Region 4, BLM administered land, and private land. It has a current financial assurance amount of $11.3 million.

6.3.11.1. WATER QUALITY PREDICTIONS SUMMARY

The Salmon-Challis National Forest has been the lead agency for all NEPA actions at the Thompson Creek Mine. NEPA was required for the new project to be permitted, and an EIS was completed in 1980. NEPA was not required for the NPDES discharge permit. In 1999 a Supplemental EIS was conducted for a plan of operation change dealing with tailings disposal. The following sections summarize the water quality information and predictions made in the NEPA documents reviewed.

1980 EIS

The 1980 EIS cites laboratory tests to characterize leachate, determine weathering effects over 20 years, and determine the quantity of acid the waste rock would consume. The specific nature of the tests and test results were not provided. The tests indicated that there was sufficient buffering capacity to neutralize acid drainage and that leachate would not contain significant concentrations of contaminants. The EIS stated that such conditions would continue for 20 years, but no basis is provided for the prediction.

The 1980 EIS did note a concern that water infiltrating waste dumps will leach materials in toxic concentrations from waste rock and that these will reach surface water. The EIS also noted that infiltration from the tailings impoundment could exceed EPA drinking water standards for iron, manganese, nitrate TDS, and zinc, which could cause Bruno Creek to exceed water quality criteria during low flow.

No acid drainage characterization tests were conducted for tailings, and according to the EIS, the tailings would be similar to low-grade ore, which did not indicate potential for acid drainage. However, tailings leachate tests showed potential for elevated levels of iron and manganese in excess of drinking water standards, and iron and zinc concentrations in excess of EPA criteria for protection of aquatic life. According to the EIS, the areal extent of potential groundwater contamination was unknown, and potential increases of metal concentrations in surface water could occur but would be similar to background levels due to dilution and biological activity. The general prediction of the 1980 EIS was that acid drainage would not occur at the Thompson Creek mine.

1999 EIS

According to the 1999 EIS, in 1988 visual signs of acid drainage were observed in the mine pit and the face of the tailings impoundment. The presence of acid drainage was subsequently confirmed in the mine pit and tailings impoundment, and in 1990 a geochemical characterization program was initiated.

Tailings Impoundment

Tailings and tailings embankment samples were collected and subjected to total sulfur, pyrite sulfur and neutralization potential analyses. In addition, selected samples were subjected to kinetic testing. Static testing results showed an average sulfur content of 0.8%, average acid neutralization potential (ANP) of 6 tons/kiloton (t/kt), acid generation potential (AGP) of 24 t/kt , net neutralizing potential (NNP) of 19 t/kt, and the average ANP/AGP ratio was 0.3 in embankment samples. Slimes (interior tailings) samples had an average ANP of 8 t/kt, NNP of 0.4 t/kt and an ANP/AGP ratio of 1.0. The EIS concluded that the static tests indicated the potential for acid drainage in embankment tailings and less potential in slimes tailings due to saturated conditions in the tailings impoundment. The acid drainage potential was confirmed by kinetic testing, with several samples producing acid drainage during the initial test cycles.

The Draft EIS contained predictions of tailings effluent water quality based on various mitigation for periods of up to 1,500 years. The potential for impacts to Squaw Creek were noted. The final EIS predictions were limited to a 100-year period and were based on results from the PYROX model. The predictions were based on assumptions that the interior slimes tailings would remain saturated (immersed in water) and the tailings would therefore not be reactive and produce acid drainage. The exterior (sand) embankment materials were expected to have excess neutralization capacity at the end of the 100-year simulation, although they could produce acid drainage beyond the 100-year period. The model results are based on the assumption that 140 feet of pyrite-depleted flotation tailings would be placed over the entire embankment surface (with pyrite enriched tailings located in the interior of the embankment). The Draft EIS predictions showed potential for acid drainage generation in 300 to 1500 years, but no impact on surface water quality was predicted, based on PHREEQE surface water quality modeling results.

Waste Rock

Waste rock samples representing various geologic units were collected and subjected to static and kinetic testing. Static testing indicated that volcanic waste rock was not acid generating, with average ANP/AGP ratio of 30:1 and an NNP of 20.6 t/kt. Static and kinetic testing on metasedimentary and intrusive rocks indicated the potential for acid drainage generation.

Long-term water quality of waste rock leachate was predicted based on geochemical testing, seepage rate predictions and existing water chemistry. HELP model simulations were used to predict the rate of seepage from the waste rock dumps. No significant acid drainage, metals leaching or impacts to surface water were expected. According to the EIS, based on existing water quality of dump effluent, the "excess" neutralization potential (from calculations on a "tonnage weighted basis," the NP:AP ratio of the waste rock is 1.5 to 3.1) and assuming mixing in surface waters.

According to the EIS, any acid-producing rock would be mitigated by special handling (segregation) and isolation techniques that are "demonstrated by their use throughout the mining industry." Potentially acid-generating waste material will be identified, placed in zones within the waste dumps and covered with compacted covers, with a final graded cap placed over the dump to reduce infiltration. Based on the mitigation employed, water quality impacts are not anticipated for either groundwater or surface water at the Thompson Creek Mine, according to the EIS.

Pit Lake

The EIS acknowledged that pit water quality may be characteristic of acid drainage and have high concentrations of molybdenum, iron and manganese. No studies had been conducted at the time of the EIS to quantitatively predict pit lake water quality. The EIS suggests that the pit will act as a terminal groundwater sink, thereby resulting in no impacts to local groundwater or surface water.

6.3.11.2. ACTUAL WATER QUALITY CONDITIONS

According to the 1999 EIS, water quality sampling errors from 1981 to 1990 prevented a reliable baseline water quality evaluation. More recent data (1991 to 1995), the interpretation of which is highly qualified in the EIS, indicated elevated levels of cadmium, copper, lead, sulfate and zinc in surface water, possibly at levels exceeding acute or chronic aquatic life standards. Tailings seepage water quality showed increases in iron, zinc and alkalinity, which, according to the 1999 EIS, were predicted in the 1980 EIS.

According to the 1999 EIS, from 1989 to 1995, sulfate concentrations in creeks downgradient of the waste rock dumps increased from 100 mg/l to 500 mg/l in one case and from 300 mg/l to 1,000 mg/l in another case. No significant changes in other parameters were so far indicated.

Monitoring of seepage from the Buckskin and Pat Hughes waste dumps indicated sulfate and selenium levels were rising since 1991. Selenium concentrations exceeded water quality standards in the seepage from both waste dumps. Thompson Creek has been ordered to meet water quality standards for selenium by the expiration date of its present NPDES permit (Dave Chambers, Center for Science in Public Participation, personal communication, 2005).

6.3.11.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.16 provides a summary and comparison of potential, predicted and actual water quality information for the Thompson Creek Mine. The accuracy of the predictions is discussed in this section.

<u>Acid Drainage and Metal Leaching from Tailings and Waste Rock, Including the Open Pit:</u> The 1980 EIS did not indicate acid drainage potential for either tailings or waste rock but did indicate metals leaching potential in tailings and waste rock. Pit lake water quality was predicted to be typical of oligotrophic mountain lakes. The 1999 EIS indicated acid drainage potential in tailings and waste rock, but acid drainage from tailings was not predicted for at least 100 years. The pit lake was predicted to be contaminated by acid drainage but was expected to act as a terminal sink and create no impacts on local water resources. Therefore, the potential for acid drainage was initially underestimated and subsequently predicted to take longer to develop than it did. However, the potential for metal leaching was noted in both EISs.

<u>Elevated Concentrations of Metals and Sulfate in Surface Water:</u> The 1980 EIS stated that water infiltrating the waste dumps could potentially leach materials in toxic concentrations that would reach surface water, and infiltration from the tailings impoundment could cause Bruno Creek to exceed water quality criteria during low flow. This EIS predicted moderate surface water quality impacts after mitigation were in place. The 1999 EIS noted potential impacts to water quality in Squaw Creek, but predicted no impacts to surface water after mitigation were in place. Therefore, potential (pre-mitigation) impacts were closer to actual impacts, and the degree of success of mitigation measures was overestimated, especially in the 1999 EIS.

Table 6.16. Thompson Creek, ID, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings	• 1980 EIS: No acid drainage potential but metals leaching potential • 1999 EIS: acid drainage potential in tailings	• 1980 EIS: dilution and biological activity • 1999 EIS: saturated conditions in the tailings impoundment to result in less acid drainage potential in slimes tailings	• 1980 EIS: water quality will be similar to background levels • 1999 EIS: acid drainage not predicted for at least 100 years	• Acid drainage observed in 1988 and confirmed in the tailings embankment Tailings seepage water had increases in Fe, Zn and alkalinity
	Waste Rock	• 1980 EIS: No acid drainage or contaminant potential • 1999 EIS: acid drainage potential in waste rock	• 1980 EIS: No mitigation identified • 1999 EIS: segregation and blending of PAG waste rock	• 1980 EIS: No impacts predicted • 1999 EIS: No impacts to groundwater predicted	• Buckskin and Pat Hughes waste dump seepage - rising SO_4 and Se levels since 1991
Surface Water	Tailings	• 1980 EIS: No potential for surface water impacts identified	• 1980 EIS: No mitigation identified	• 1980 EIS: No impacts predicted	• Elevated levels of Cd, Cu, Pb, SO_4 and Zn in surface water (1991-1995) • Increasing downstream SO_4 concentrations (100 to 500 and 300 to 1,000 mg/l), 1989 to 1995
	Waste Rock	• 1980 EIS: No potential for surface water impacts identified • 1999 EIS: acid drainage potential in waste rock	• 1980 EIS: No mitigation identified • 1999 EIS: segregation and blending of PAG waste rock	• 1980 EIS: No impacts predicted • 1999 EIS: No significant acid drainage or metals leaching or impacts to surface water are predicted	
Pit Water	Open Pit	• 1980 EIS: No potential for pit water impacts identified • 1999 EIS: pit water quality may be characteristic of acid drainage and have high concentrations of contaminants	• 1980 EIS: No mitigation identified • 1999 EIS: Pit will be terminal sink	• 1980 EIS: No impacts predicted • 1999 EIS: no impacts on local groundwater or surface water	• Visual signs of acid drainage observed/confirmed in mine pit (1988)

6.3.12. BEAL MOUNTAIN, MONTANA

The Beal Mountain Mine, owned by Pegasus Gold Mining Company, was in operation from 1989 to1998. The primary commodities mined were gold and silver from open pit mining, and heap leach processing was used. It disturbs 429 acres on Deerlodge National Forest in U.S. Forest Service Region 1. Due to ongoing water discharge issues and lawsuits from local public interest groups, the site was declared a Forest Service CERCLA site in 2003 and has been the subject of on-going remediation efforts since that time. The bond in 1998, when Pegasus Gold Mining Company went bankrupt, was $6.3 million. To date, the State of Montana and Forest Service have spent in excess of an additional $6 million in remediation costs.

6.3.12.1. WATER QUALITY PREDICTIONS SUMMARY

The Deerlodge National Forest and Montana Department of Environmental Quality (formerly Department of State Lands) were the lead agencies for NEPA and Montana Environmental Policy Act (MEPA) actions at the Beal Mountain Mine. NEPA was required for the new project to be permitted, and an EA was completed in 1988. In 1993 an EIS was conducted for mine expansion. The NPDES permit was not required or part of the NEPA/MEPA action for the original operations, which were supposed to be zero discharge. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1988 EA

According to the EA, the sulfide content of the ore ranged from 3 to 8% (pyrrhotite, pyrite, chalcopyrite, with traces of molybdenite and arsenopyrite), but a rind of clay and /or iron oxides enclosing fresh sulfides in a cherty matrix account for low acid production. Geochemical characterization tests conducted included whole rock analysis, ABA and EP Toxicity tests. Constituents of concern identified included arsenic, cadmium and lead. Results of the acid-base testing indicated the waste rock would not generate acidic waters and would not be a significant source of metals due to the low sulfide content of the waste material and the large acid-buffering capacity of the majority of the waste rock. Tests on waste rock indicated that a leachate developed under acidic conditions would be innocuous. Impact from residual cyanide from the leaching process was predicted to be minor.

Mitigation identified in the EA included diversion of stormwater and collection of pit water for process use. The leach pad and solution ponds would be lined and have either a blanket drain or leak detection system that would be monitored. The pit would be backfilled, underlain by a layer of limestone and gravel and be free-draining, resulting in no pit lake. The leach pad would be rinsed to address residual cyanide followed by natural degradation, dilution and "mobilization." Water quality impacts from the leach pad were expected to be minor and probably unpredictable.

1993 EIS

The 1993 mine expansion EIS included geochemical characterization testing, including static ABA, short term leach tests (EPA Method 1310), kinetic tests (15 week humidity cell tests) and trace element analysis. Constituents of concern identified include nitrate, sulfate, cyanide, increased sediment and TDS. Due to the presence of pyrite, pyrrhotite and iron disulfides associated with the deposit, the potential for acid production exists. Geochemical material characterization tests for the main Beal and South Beal deposits indicate a low potential for acid formation. However, the release of sulfates and metals into surface waters is still considered to be a possibility, and these substances could become mobile regardless of acid production. Kinetic testing (humidity cell tests) was conducted for 15 weeks, and the results indicated that the South Beal quartzite waste would not be acid producing. Samples of main Beal waste with higher sulfide content were chosen to test a worst-case scenario, and static tests showed that the potential for acid generation exists for these samples. Leachate extraction tests resulted in no metals concentrations exceeding regulatory limits, and metals mobility was predicted to be minimal. Results from static tests on heap leach material suggested an uncertainty as to whether sulfate release and metals leaching would eventually become a concern. Results from kinetic tests on the heap leach material showed sulfate release for all samples, indicating a possibility for oxidation of pyrite. A chemical analysis of humidity cell leachate after week nine indicated the possibility of arsenic mobility.

According to the EIS, successful reclamation would minimize any potential for impacts to groundwater from the release of sulfate and would reduce infiltration. Addition of main Beal waste rock as backfill material into South Beal pits could provide a new source of potentially acid generating material, but testing of backfill material before placement, segregating acid producing material and keeping the pit floor above the water table were expected to prevent negative impacts to water. The leach pad has a liner and effluent is controlled, resulting in only minor expected impacts from arsenic and metals. If pyrite oxidation occurs, waste would be segregated in order to isolate reactive waste and cap it. Addition of South Beal waste rock to the waste rock dump is not expected to produce acid or release contaminated leachate, but could provide neutral material for capping to help isolate potential leachable contaminants.

The LAD (land application discharge) system for disposal of excess leach solution demonstrated that all contaminant levels, including arsenic, are successfully attenuated prior to discharge. A cyanide destruction water treatment plan is used prior to LAD disposal. Addition of lime to waste rock will occur if necessary. Pit bottoms will be above the water table. Backfilling and capping were expected to prevent water accumulation in the pits. Pit floors composed of marble bedrock were expected to reduce the potential for contaminant leaching. Any water that may accumulate in pits prior to backfilling would be used for irrigation on reclaimed portions of the waste rock facilities or other areas. The South Beal heap and waste rock area will be monitored to determine whether it will produce acid drainage.

Predicted impacts to groundwater from mining the South Beal Pits are expected to be minimal because the pits would be open for only one to two years. The water table under the pits is 25 to 50 ft below the estimated levels of the pit floors, so groundwater would not come in contact with backfilled waste from main Beal pit. If water infiltrates backfilled pits, sulfate could be produced and enter groundwater. Sulfate is expected to be released from South Beal ore, but the pH of the water is expected to remain neutral. Concentration of nitrate and sulfate released from the waste rock facilities may continue to increase with the addition of the South Beal waste. The potential that nitrate will discharge to groundwater downgradient of the pits into German Gulch was expected to be minimal due to the distance between the pits and the stream. Beal Mine was predicted to have both long- and short-term environmental effects in German Gulch; however, these effects were not predicted to be significant in terms of either areal extent or severity of impact. Results of leach tests (EPA Method 1310) indicated that metals mobility should be minimal. Open pit, waste rock dump and heap materials are not expected to cause acid drainage, either during operations or after mining. The heap is part of a zero discharge circuit and is not expected to release any water to the surface.

6.3.12.2. ACTUAL WATER QUALITY CONDITIONS

According to the 1993 EIS, elevated levels of sulfate were detected at the monitoring stations near the main Beal waste rock facility. Although the source has not been verified, it could be a precursor to acid drainage. Currently, sulfate concentrations in seeps emanating from below the main Beal waste rock dump are increasing. This could either be due to dissolution of gypsum incorporated in the rock, dissolution of soil amendments, application of a sulfate used for chemical dust abatement, or the oxidation of iron disulfides in mined material. Water quality in German Gulch has changed since baseline data were collected, showing that TDS, sulfate and nitrate concentrations have increased considerably. Currently, State Water Quality Standards (SWQS) are exceeded at some monitoring stations, demonstrating that existing Best Management Practices or mitigation measures are not effective. Nitrate concentrations have increased in groundwater in the vicinity of the main Beal project relative to background baseline conditions.

Existing Conditions Report

According to the February 2004 Existing Conditions Report (ECR), developed as part of the Engineering Evaluation /Cost Analysis (EE/CA) for this CERCLA site, surface water sampling results from German Gulch showed that concentrations of nitrate (MCL = 10 mg/l) and sulfate were less than 10 mg/l. Total recoverable concentrations of most metals and metalloids (including arsenic and copper) were below chronic aquatic life standards, while total recoverable iron concentrations in German Gulch did exceed secondary MCL values near the mine site. Selenium concentrations were well below the chronic aquatic life standard of 0.005 mg/l. The total concentration of cyanide in German Gulch was 0.008 mg/l, slightly higher than the chronic standard of 0.0052 mg/l. Total recoverable concentrations of copper were below the chronic aquatic standard at all stations in German Gulch in 2003. Selenium concentrations measured in December 2003 were 0.011 mg/l.

Groundwater quality monitoring well data indicated that groundwater in the LAD area exceeded standards for nitrate, iron and cyanide and had elevated total dissolved solids concentrations. Cyanide was not detected in the LAD area groundwater prior to 2001 when the LAD was initiated. Springs below the LAD area also showed appreciable increases in cyanide and selenium concentrations. Concentrations of selenium, sulfate, nitrate and total dissolved solids were elevated in seeps sampled at the toe of the waste rock dump.

Geochemical data from both static and kinetic tests indicated that roughly one-third of the waste rock and ore mined from the Beal Pit is potentially acid generating, one third is not and the remaining one-third has uncertain potential to generate acid. Geochemical characterization test results from South Beal pit ore and waste rock suggested a low potential for acid drainage from the pit highwalls and waste rock, and a high potential from residual ore. However, the relatively small amount of residual ore is not expected to generate enough acidity to overwhelm the neutralization potential of the surrounding rock.

Static testing of spent ore indicated a high potential for acid generation; however, kinetic tests indicated a low potential for acid generation. Alkalinity and pH values have decreased somewhat following cessation of leaching operations, indicating that the neutralizing capability of the heap is slowly being depleted. Selenium and copper concentrations in the pad appear to be declining.

Water emanating from the toe drain collection system is pumped to a storage pond and has elevated selenium, sulfate and nitrate concentrations and cannot be discharged directly to surface water or groundwater without treatment.

Current leach pad water quality has elevated concentrations of sulfate (2,600 mg/l), selenium (0.38 mg/l), arsenic (0.16 mg/l), iron (4.0 mg/l, copper (0.42 mg/l), total cyanide (9.5 mg/l) and WAD cyanide (0.061 mg/l) Alkalinity values have decreased to about 100 mg/l ($CaCO_3$ equivalent).

6.3.12.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.17 provides a summary and comparison of potential, predicted and actual water quality information for the Beal Mountain Mine. The accuracy of the predictions is discussed in this section.

Increases in/Exceedences of Cyanide, TDS, Sulfate and Nitrate Concentrations in Surface Water: The 1988 EA predicted that the low sulfide content, high buffering capability and low metals concentrations would prevent degradation of water from the waste rock dump. The 1988 EA also indicated that there was only a minor potential for acid drainage from leach pad and waste rock material, and water quality was not predicted to be impacted. However, the increased sulfate concentrations may be a precursor to acid drainage. The 1988 EA predicted only a minor impact from residual cyanide from the leaching process. The leach pad liner system was expected to mitigate the potential for cyanide contamination, but it did not. The 1993 EIS indicated some potential for acid drainage from leach pad material and waste rock, but results of short-term leach tests indicated that metals mobility would be minimal. Therefore, predictions made in the new project EA and the 1993 EIS noted some potential for acid drainage and increased sulfate concentrations and underestimated the potential for contamination of surface water from the leach pad and waste rock.

Exceedences of Nitrate, Cyanide, and Iron Concentrations in Groundwater: As noted above, the leach pad liner system was expected to mitigate the potential for cyanide contamination. The open pit, waste rock dump, and heap were not predicted to cause acid drainage during operations or after mining, but the 1993 EIS did indicate some potential for acid drainage from leach pad and waste rock material. Therefore, predictions made in the new project EA and the 1993 EIS noted some potential for acid drainage, underestimated the potential for metals leaching and underestimated the potential for contamination of groundwater from the leach pad and waste rock.

Table 6.17. Beal Mountain, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Leached Ore	• 1988 EA: Impact from residual cyanide from the leaching process was predicted to be minor and probably undetectable • 1993 EIS: South Beal ore in leach pad could be acid generating but expected to remain neutral	• 1988 EA: solution ponds equipped with sump, leak detection • 1988 EA: leach pad rinsed to address residual cyanide followed by natural degradation, dilution and "mobilization." • 1993 EIS: effluent treated for cyanide and disposed by LAD	• 1988 EA: Water quality impacts from the leach pad would be minor and probably unpredictable • 1993 EIS: only minor impacts from As via LAD 1993 EIS: Heap is part of a zero discharge circuit and would not release any water to the surface.	• 2004 ECR: LAD of leach pad leachate following water treatment resulted in contamination of groundwater exceeding standards for nitrate, iron, cyanide. Accidence of cyanide concentrations in surface water
	Waste Rock	• 1988 EA: Low acid drainage and metals potential suggests that degradation of water will not occur from the waste rock dump • 1993 EIS: some potential for acid drainage and release of sulfates and metals to water resources	• 1988 EA: No mitigation identified • 1993 EIS: reclamation would minimize any potential for impacts to groundwater from the release of sulfates and reduce infiltration • 1993 EIS: segregation and blending of PAG waste rock with lime added if necessary	• 1988 EA: No impacts predicted • 1993 EIS: Concentration of NO_3 and SO_4 releases from waste rock facilities may continue to increase	• 1993 EIS: Increased SO_4 concentrations in waste rock toe seeps - possible precursor to acid drainage. Increases in TDS, SO_4, NO_3 in German Gulch relative to baseline data. • 2004 ECR: elevated Se, sulfate, nitrate and TDS in seeps below waste rock
Pit Water	Open Pit	• 1988 EA: Mine pit water expected to contain elevated ammonia and nitrate/ nitrite from blasting.	• 1988 EA: Diversion of stormwater and pit water for process use • 1988 EA: pit backfilled, lined with limestone and gravels, free-draining; rock in pit would neutralize contaminants	• 1988 EA: No pit water predicted • 1993 EIS: Predicted impacts would have little if any effect on groundwater.	2004 ECR: water from the open pit toe drains has elevated selenium, sulfate and nitrate and requires capture and treatment

6.3.13. BLACK PINE, MONTANA

The Black Pine Mine, owned by ASARCO, was in operation from 1974 to 1989 but was closed at various points during this period. The primary commodities mined were gold, silver and copper from underground mining, using flotation and gravity processing methods. The ore has also been mined as a silica flux for ASARCO's East Helena Smelter. It disturbs 429 acres on the Deerlodge National Forest in U.S. Forest Service Region 1 and has a current financial assurance amount of $8.07 million.

6.3.13.1. WATER QUALITY PREDICTIONS SUMMARY

The Deerlodge National Forest and Montana Department of Environmental Quality (formerly Department of State Lands) were the lead agencies for NEPA and MEPA actions at the Black Pine Mine. NEPA was required for mine re-opening after an extended closure period, and an EA in the form of a Preliminary Environmental Review (PER) was completed in 1981. In 2003 an EA was conducted for short-term reclamation due to the existence of water quality issues. In 2004 another EA was conducted to address long-term reclamation. The NPDES permit was not required or part of the NEPA/MEPA action for the original operations, which were supposed to be zero discharge. The following sections summarize pertinent information in the NEPA documents reviewed.

1981 Preliminary Environmental Review

The primary minerals identified were sulfides and sulfosalts including hubnerite, tetrahedrite, pyrite and galena. Secondary mineral association consists of malachite, pyromorphite, oxidized lead, antimony and native silver. No geochemical characterization testing was performed, so the potential for acid drainage or leaching of contaminants was not identified in the PER. The amount of seepage from the tailings impoundment to groundwater was predicted to be low (14.6 gpm), and constituents reporting to the tailings impoundment were considered to be of low concentrations and degradable. Impacts to groundwater from tailings were predicted to be minimal. According to the PER, impacts to surface water systems in the project area will be minimal. No planned discharge to surface waters will occur. The tailings impoundment was designed as a closed cycle system.

2003 EA

According to the 2003 EA, the waste rock dump contains primarily quartzites and argillites of the Spokane Formation and ore vein material. Pyrite, iron staining and copper-bearing minerals can be seen on the surface of the dump, and copper staining from mobilization of copper minerals can be seen on rocks, bones and other debris on the surface of the dump. No sampling of the waste rock dump for geochemical characterization was performed. However, constituents of concern identified from existing waste rock dump seepage included sulfate, copper, zinc, iron, cadmium and low pH.

Mitigation identified in the EA included relocation and improvements to the seepage collection systems below the waste rock dump, consolidation/placement of contaminated materials on top of the waste rock dump and regrading the waste rock dump from angle of repose to a 3:1 slope.

2004 EA

No additional geochemical characterization information or water quality predictions were performed for this EA. The EA addressed final reclamation by requiring reclamation of the waste rock dump with a composite engineered cover consisting of a six 12-inch, low-permeability layer overlain by a drainage layer (sandy gravel) and then a soil cover (six inches of topsoil underlain by 18 inches of subsoil). Additional areas of contaminated soil would also be addressed.

The EA included a contingency to require more permanent long-term water management measures if the proposed reclamation measures are not effective, and the current bond assumes those measures will be necessary. The water treatment would most likely involve capture, pumpback, treatment and disposal.

6.3.13.2. ACTUAL WATER QUALITY CONDITIONS

The 2003 EA was initiated to reduce on-going water quality impacts caused by leachate from the waste rock dump, and it discusses these impacts. In 2000 MDEQ identified acid drainage and metals in springs on site with elevated levels of sulfate, metals and low pH. The 2003 EA showed waste rock was discharging acid drainage and metals to underlying groundwater and springs. Seepage collection and reclamation of the waste rock dump was performed to mitigate acid drainage. The leachate runs overland and off site and has killed vegetation in the area of the flows. Several ephemeral springs and one perennial spring issuing from the waste rock dump are contaminated by the dumps and are acidic (2.6 to 4.7) and high in sulfate, copper, zinc, iron and cadmium. The springs drain into groundwater and ephemeral drainages that flow into Smart Creek.

6.3.13.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.18 provides a summary and comparison of potential, predicted and actual water quality information for the Black Pine Mine. The accuracy of the predictions is discussed in this section.

Impact of Acid Drainage from Waste Rock Dump on Springs, Groundwater, and Ephemeral Drainages: No geochemical testing was performed on waste rock in any of the environmental reports. Information on geology and mineralization gave some hint of the potential for acid drainage (sulfides in quartzites with carbonates on site, but not in ore body), but this information was not evaluated or used as a basis for ordering geochemical testing. The only identified source of potential water contamination in the 1981 PER was the tailings impoundment. The 1981 PER indicated no potential for acid drainage or contaminants with no planned discharge to surface water and predicted minimal impacts to water resources. The 2004 EA indicated long-term potential for acid drainage and metals from the waste rock dump and underground workings. Therefore, the observed water quality impacts to springs, groundwater and surface drainages were not predicted. No geochemical testing on waste rock was performed, and the mineralization, although suggestive of potential acid generation, was not further investigated. The only identified potential source of water contamination, the tailings impoundment, has not yet been shown to be impacting groundwater.

Table 6.18. Black Pine, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Waste Rock	• 1981 EA: no potential for acid drainage or leaching of contaminants was identified • 2003 EA: existing leachate from the waste rock dump contaminating groundwater and springs on site with acid drainage and metals. • 2004 EA: long-term leachate from the waste rock dump and potential water quality problems from underground mine workings	• 1981 EA: No planned discharge to surface waters will occur • 2003 EA: relocation and improvements to the seepage collection systems below the waste rock dump; consolidation /placement of contaminated materials on top of the waste rock dump; and regrading the waste rock dump from angle of repose to a 3:1 slope. • 2004 EA: reclamation of the waste rock dump with a composite engineered cover; contingency to require more permanent long-term water management measures if the proposed reclamation measures are not effective o capture, pumpback, treatment and disposal.	• 1981 EA: impacts to surface water systems in the project area will be minimal • 2003 EA: reduction of existing water quality impacts is expected • 2004EA: long-term reduction and prevention of future water quality impacts is expected	2000 DEQ: identified existing leachate from the waste rock dump contaminating springs on site showed elevated levels of sulfates, copper, zinc, iron, cadmium, and low pH (2.6 - 4.7).

6.3.14. GOLDEN SUNLIGHT, MONTANA

The Golden Sunlight Mine, owned by Placer Dome, Inc., has been in operation since 1983. The primary commodities mined are gold and silver from open pit and some limited underground mining, using cyanide vat leach and gravity processing methods. It disturbs 2,967 acres on private, state and BLM lands. It has a current financial assurance amount of $64.1 million.

6.3.14.1. WATER QUALITY PREDICTIONS SUMMARY

The Bureau of Land Management and Montana Department of Environmental Quality (formerly Department of State Lands) were the lead agencies for NEPA and MEPA actions at the Golden Sunlight mine. NEPA and MEPA were required for the new project to be permitted, and an EIS was completed in 1981. A subsequent EA for expansion was conducted in 1990, followed by an additional EIS for mine expansion in 1997. Currently an additional EIS is being developed for consideration of open pit backfilling. The following section summarizes the pertinent information in the NEPA documents reviewed.

1981 EIS

Only ABA tests were performed. No constituents of concern were identified. Results of testing confirmed the potential for the ore to produce acid. According to the EIS, the potential for acid mine drainage from the proposed project was considered to be minimal, based on the previous, historic mining activity and waste dump development on the project site that had not resulted in acid mine drainage. There was also a general lack of a water discharge from existing underground workings at the mine.

The EIS addressed the potential for groundwater contamination from tailings leachate, which contained cyanide. Mitigation identified in the EIS included the use of finger drains, a clay liner, cutoff trench and the impervious nature of the underlying sediments. Seepage would be collected in ditches and pumped back to the impoundment. Normal operation of the proposed facilities would not result in a significant adverse impact to the areas existing subsurface and surface water resources. The risk to groundwater after mitigation was predicted to be low. The design approach was projected to achieve a zero discharge facility. The infiltration of mining-impacted water to the groundwater system was predicted to be very localized and not cause any measurable change in groundwater quality.

1990 EA

The EA identified sulfide mineralization, with waste rock containing 1 to 5 % sulfides, of which 99 % was pyrite with minor amounts of chalcocite, chalcopyrite, bornite, galena, sphalerite and barite. Oxidation of waste rock was expected to be generally limited to within 100 ft of the surface. ABA, EP Toxicity, total sulfur and sulfur fractionation, and “laboratory weathering” geochemical characterization tests were performed. Constituents of concern identified included low pH, elevated levels of metals, nitrate and high salt concentrations.

According to the EA, the pH value for waste rock averaged 4.2 (acid generating). All laboratory weathering samples of waste rock produced acid. All samples of unoxidized mudrock near the breccia ore body produced acid in the laboratory weathering tests. All samples of oxidized mudrock also produced acid in the laboratory weathering tests. If reclamation does not eliminate available oxygen and water, the tailings are predicted to eventually acidify. Waste rock piles are also predicted to eventually acidify from oxygen convection due to the high sulfide content and lack of a waste rock cap. Ultimate water quality in the mine pit is uncertain, but leachate analysis suggests the water would have low pH and elevated levels of metals, nitrate and salts in excess of the natural groundwater conditions. The EA suggested that water seeping from the pit would be modified by “a variety of unidentifiable geochemical processes,” and this flow would reduce the quality of the receiving water and exceed water quality standards.

According to the EA, engineered mitigation would consist of an impoundment designed with an amended soil liner and a piping system above the liner to carry tailing seepage through the embankment face to a collection system and the mill circuit. The slurry wall would intercept the majority of seepage from the impoundment. It is anticipated that seepage to the east and south of the impoundment may occur. In time, a decrease in the effectiveness of the plumbing system for the impoundment is expected. This decrease in efficiency may result in a rise of phreatic levels within the impoundment and drainage through the impoundment bottom or through the embankment face.

To meet the requirements of the Montana Metal Mine Reclamation Act (MMRA), GSM committed to treat any discharge from the mine pit, waste rock dumps and tailings impoundments. The 1990 EA states that "Treatment in perpetuity has never been addressed by the regulatory agencies."[3] In addition, a mass balance model was used to justify the recommendation for a two-ft waste rock and two-ft soil cap cover to minimize infiltration and leachate quantities.

1998 EIS

The 1998 EIS resulted from citizen lawsuits that appealed the 1990 EA decision. This EA found that there would be no significant impacts, even though the high potential for acid drainage and substantial reclamation and water treatment requirements were identified..

The EIS identified high potential for acid drainage and contaminant leaching. The potential contaminants list was increased in the 1998 EIS to include aluminum, arsenic, cadmium, copper, zinc, pH, sulfate, chromium, iron, lead, manganese, nickel and selenium. Contaminants typically exceeded drinking water standards by 10 times or more in waste rock pore water extracts. Groundwater contamination was predicted to occur in tens to hundreds of years. Pit water, if allowed to form, was similarly expected to be characteristic of acid drainage. The tailings impoundments were also expected to become acid generating over the long-term.

The 1998 EIS acknowledged the presence of acid drainage-like solutions from springs in the project area, containing elevated concentrations of sulfate and trace metals. These springs were considered natural because of the abundant ferricrete associated with them, suggesting that acid drainage has been produced by Bull Mountain for some time. However, it is possible that mining activity caused the elevated concentrations, and no baseline water quality data are available to determine the cause or causes of the elevated concentrations.

An acid drainage transport model was used to estimate the potential for contamination from the waste rock dumps to affect surface water in the Jefferson River. HELP modeling was used to estimate precipitation inflow rates into the waste rock dumps. A mixing cell model was used to predict interaction of leachate with the groundwater flow system and eventual transport to surface water. Dump seepage was predicted to reach the water table within 30 to100 years, followed by a period of approximately 2,000 years where seepage was primarily characterized by high sulfate levels, followed by a steep increase in acidity and metals contamination beginning in approximately 3,000 years and extending for up to 10,000 years in the future. Best case results suggested the most significant impacts would not occur for up to 5,000 years in the future, while worst case results suggested the same impacts would occur approximately 600 years in the future.

In addition to an engineered cover (2 ft non acid-generating material and 2 ft soil) and perpetual waste rock seepage water treatment, mitigation included installation of drains and other seepage capture devices to reduce the amount of acid drainage that reaches groundwater.

The tailings impoundments were expected, over the short-term, to continue to leak cyanide-containing solutions into groundwater and to require pumpback systems to mitigate the groundwater plume and prevent it from reaching surface water. The No. 1 tailings impoundment was expected to continue leaking until it is effectively reclaimed, and localized leaks were expected to occur from the No. 2 tailings impoundment over the long-term. After closure the leachate was expected to become acidic. However, the EIS predicted that an engineered cover (2 ft NAG and 2 ft

[3] It appears that this may be the first regulatory reference in the U.S. dealing with hardrock mine sites that acknowledges the possibility of perpetual treatment as a potential scenario.

soil) would decrease leachate infiltration to groundwater and little or no impact to groundwater would occur. Present day tailings impoundment plume mitigation included groundwater pumpback systems, slurry walls and landowner buyouts as well as replacement water provisions.

No pit pond would be allowed to form if it exceeds Montana surface water quality standards. Pit water treatment would be required if necessary for discharge.

2005 EIS

In 2002 another citizens' lawsuit resulted in a requirement for the Golden Sunlight Mine to prepare an EIS to address pit backfilling, which the court ruled the mine was required to do in order to meet the State's constitutional requirements. The Draft EIS was issued in 2005. It contains an analysis of the potential for backfilling of the open pit to impact groundwater and surface water quality and will most likely include predictions for both backfilling and non-backfilling as well as pit lake scenarios.

6.3.14.2. ACTUAL WATER QUALITY CONDITIONS

According to the 1998 EIS, monitoring of existing waste rock dumps showed sulfide oxidation and potential for acid drainage, with some piles already producing acid drainage. Evidence shows some springs on the project site were impacted, but larger impacts to groundwater or surface water from the waste rock dumps have not been evident to date.

The primary source of existing groundwater contamination at Golden Sunlight is the tailings impoundment. The groundwater contains cyanide and copper concentrations above standards and has required numerous mitigation, as described in the previous section.

6.3.14.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.19 provides a summary and comparison of potential, predicted and actual water quality information for the Golden Sunlight Mine. The accuracy of the predictions is discussed in this section.

<u>Groundwater Contamination from Tailings Impoundment</u>: Potential groundwater contamination with cyanide and metals from the tailings impoundment was identified in the 1983 EIS, but mitigation (clay liner, finger drains, leachate collection) were predicted to prevent any impacts to groundwater. The 1990 EA stated that capture of the tailings plume would prevent more extensive groundwater contamination, but capture was not entirely effective. Therefore, the estimated potential (pre-mitigation) impacts of cyanide and metals from the tailings impoundment were accurate. The predictions that the tailings impoundment mitigation would prevent groundwater contamination and that plume capture would limit further groundwater impact were not accurate.

<u>Acid Drainage in Waste Rock Pore Fluids, Pit Water, and Springs Downgradient of Waste Rock Dumps</u>: Geochemical characterization conducted for the 1981 EIS identified the potential for acid drainage, but because historic operations had not resulted in acid drainage, the potential was considered to be low. In addition, the acid-base accounting results were accompanied by a statement from the laboratory that laboratory results were not representative of field conditions (due to grinding of sample), and that acid drainage generation could be less important than indicated by the test results. Therefore, acid-base accounting tests did predict the acid drainage that ultimately developed at the site, but the prediction that acid drainage would not develop based on information from historic operations was not accurate.

Table 6.19. Golden Sunlight, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings	• 1981 EIS: Geochemical tests indicate acid drainage potential but site indications used to suggest low actual potential. • 1981 EIS: Potential for contamination of groundwater from tailings solution containing cyanide. • 1990 EA: Potential for acid drainage and metals in leachate • 1998 EIS: Short-term tailings leak containing cyanide and other contaminants expected to continue • 1998 EIS: Long-term potential for tailings to go acid	• 1981 EIS: Facility design to prevent groundwater and surface water impacts. o use of finger drains o clay liner o cutoff trench o impervious nature of the underlying sediments • 1990 EA: Capture of contaminated groundwater o Slurry walls and downgradient wells • 1998 EIS: Capture of contaminated groundwater o Slurry walls and downgradient wells o landowner buyouts o replacement water provisions o perpetual treatment of tailings seepage • 1998 EIS: Reclamation cover to decrease long-term potential for impacts from acid drainage	• 1981 EIS: Risk to groundwater "slight" • 1990 EA: Prevent contamination from becoming more extensive in groundwater and will protect surface water • 1998 EIS: Little or no long-term impact to groundwater from acid drainage. No impacts to groundwater outside of existing cyanide plume.	• 1990 EA: Contamination of cyanide and copper in downgradient wells • 1998 EIS: Continued contamination of cyanide and copper in dowgradient wells • Water Quality Monitoring: Capture not 100% efficient due to operational problems

Table 6.19. Golden Sunlight, MT, Potential, Predicted and Actual Impacts (continued).

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Waste Rock	• 1981 EIS: Geochemical tests indicate acid drainage potential but site indications used to suggest low actual potential • 1990 EA: Significant potential for acid drainage and metals in waste rock leachate • 1998 EIS: Significant potential for impacts from acid drainage and metals over long-term	• 1981 EIS: No mitigation identified as needed • 1990 EA: Capture of contaminated groundwater ○ Slurry walls and downgradient wells • 1990 EA: Engineered covers to reduce leachate production • 1998 EIS: Capture of contaminated groundwater ○ Slurry walls and downgradient wells ○ installation of drains and other seepage capture devices • 1998 EIS: Reclamation cover to decrease long-term potential for impacts from acid drainage	• 1981 EIS: Risk from acid drainage "minimal" • 1990 EA: Mitigation to prevent significant long-term impacts from acid drainage • 1998 EIS: Mitigation to prevent significant long-term impacts from acid drainage in surface water. No impacts to groundwater outside of proposed mixing zone.	Water Quality Monitoring: No actual impacts noted to date although springs near east waste rock dump and pore water in all waste rock dumps indicate long-term acid drainage and metals leaching impacts
Groundwater, Surface Water and Pit Water	Open Pit	• 1983 EIS: Pit not expected to go below groundwater level • 1990 EA: Significant potential for acid drainage and metals in leachate from open pit • 1998 EIS: Pit water expected to be characteristic of acid drainage	• 1983 EIS: No mitigation identified as needed • 1990 EA: Capture of contaminated pit water • 1998 EIS: Capture and treatment – no pit lake allowed to form	• 1983 EIS: no impacts to water quality • 1990 EA: Mitigation to prevent significant long-term impacts from acid drainage • 1998 EIS: Mitigation to prevent significant off-site impacts from acid drainage	Water Quality Monitoring: Monitoring of pit water indicates acid drainage characteristics

6.3.15. MINERAL HILL, MONTANA

The Mineral Hill Mine (also known as the Jardine Joint Venture), owned by TVX Gold Inc., was in operation from 1989 to1996. The primary commodities mined were gold and silver from an underground mine that used cyanide vat leach processing methods. It disturbs 106 acres on private and Gallatin National Forest lands in U.S. Forest Service Region 1. It has a current financial assurance amount of $8.5 million.

6.3.15.1. WATER QUALITY PREDICTIONS SUMMARY

The Gallatin National Forest and Montana Department of Environmental Quality (formerly Department of State Lands) were the lead agencies for NEPA and MEPA actions at the Mineral Hill Mine. NEPA and the Montana Environmental Policy Act (MEPA), which closely mirrors the federal law, were required for the new project to be permitted, and an EIS was completed in 1986. A subsequent EIS for reclamation and closure was conducted in 2001. The following sections summarize the pertinent information on water quality from the NEPA documents reviewed.

1986 EIS

According to the 1986 EIS, minerals in the gold-bearing zone included arsenopyrite, pyrrhotite, pyrite, chlorite, quartz and amorphous carbon. Metamorphosed marine sediments host the gold ore. Geochemical characterization testing consisted of a batch extraction leach test on the tailings material. The leachate the from batch extraction contained elevated cyanide as free cyanide, arsenic and manganese. Arsenic and cyanide contamination from old tailings on the site was also mentioned as affecting background water quality. Identified potential groundwater impacts (to Bear Creek alluvium) included direct seepage from the tailings dump and production of leachate in mine workings and backfill.

The lack of water in the workings (location above the water table) were expected to limit the potential for acid drainage. Removal and reprocessing of old, existing tailings piles was proposed to address historic tailings impacts on water quality at the site. Tailings from current mining would not be dewatered before backfilling; however, slurry would be controlled by ditches in the mine, collected in underground sumps and pumped back to the mill circuit. Tailings disposed on surface would be dewatered and placed in a lined repository.

2001 EIS

According to the EIS, mining operations ceased before the originally anticipated life-of-mine. Changes in proposed reclamation techniques and water management practices prompted the EIS.

The tailings facility design resulted in unanticipated lateral flow that escaped the liner system, resulting in contamination of alluvial groundwater and surface water. The seepage contains cyanide, nitrate, manganese, sulfate, arsenic and TDS. The proposed mitigation for the discharge would involve capture and treatment of the leachate with discharge to the vadose zone for evapotranspiration and the use of a 48-inch thick water balance cover to reduce seepage.

Modern mining operations impacted the historic flow from the mine, which was less than a few gallons per minute (gpm), resulting in an increased flow of approximately 15 gpm with arsenic concentrations in excess of standards. The proposed mitigation for the impacts would involve treating the 15 gpm flow to reduce arsenic to acceptable levels and discharging to groundwater (versus present discharge to surface water).

Proposed long-term mitigation included replacement of the water treatment system and long-term monitoring and maintenance for 100 years; financial assurance insured those operations.

6.3.15.2. ACTUAL WATER QUALITY CONDITIONS

Groundwater and surface water was contaminated by tailings leachate, which contained cyanide, nitrate, sulfate, TDS, manganese and arsenic. Increased flow from the mine adit contains arsenic in excess of the mine's NPDES discharge standards.

6.3.15.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.20 provides a summary and comparison of potential, predicted and actual water quality information for the Mineral Hill mine. The accuracy of the predictions is discussed in this section.

Table 6.20. Mineral Hill, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings	• 1986 EIS: potential for elevated cyanide, arsenic and manganese in tailings leachate to contaminate groundwater • 2001 EIS: potential for cyanide, arsenic, manganese, sulfate, nitrates and TDS in tailings leachate to contaminate alluvial aquifer and surface water	• 1986 EIS: Tailings dewatered and placed in a lined repository • 2001 EIS: capture and treatment of the leachate with discharge to the vadose zone; water balance cover to reduce seepage	• 1986 EIS: no surface water impacts predicted • 2001 EIS: no impacts predicted as long as mitigation is maintained (100 years)	2001 EIS: tailings leachate containing cyanide, nitrate, manganese, sulfate, arsenic and TDS escaped the liner system and caused exceedences in alluvial groundwater and surface water
	Underground Workings	• 1986 EIS: potential for acid drainage from mine workings or backfill to contaminate alluvial aquifer • 2001 EIS: no information	• 1986 EIS: none • 2001 EIS: water treatment to reduce arsenic to acceptable levels and discharge to groundwater	• 1986: no impacts predicted • 2001 EIS: no impacts predicted as long as mitigation is maintained (100 years)	• 2001 EIS: flow from mine workings of approximately 15 gpm that contained arsenic in excess of standards

<u>Contamination of Alluvial Groundwater and Surface Water by Tailings Seepage:</u> Geochemical characterization (batch leach test) conducted for the 1986 EIS identified the potential for elevated concentrations of cyanide, arsenic and manganese in tailings leachate. Tailings were dewatered and placed in a lined repository, and no impacts to water resources were predicted in the 1986 EIS after mitigation were in place. The potential for seepage of tailings leachate to groundwater was identified in the 1986 EIS. The 2001 EIS identified the potential for alluvial groundwater and surface water contamination with cyanide, arsenic and manganese (as identified in 1986), as well as sulfate, nitrate and TDS (not predicted as contaminants of concern in the 1986 EIS). The liner system in the tailings impoundment failed to prevent lateral flow of leachate. Therefore, geochemical characterization did predict the observed increases in three of six constituents in tailings leachate, but post-mitigation predictions were inaccurate because the mitigation were not able to prevent impacts to groundwater and surface water resources.

<u>Increased Volume and Exceedence of Arsenic Standard in Adit Drainage:</u> The potential for leakage from mine workings to Bear Creek alluvium was identified in the 1986 EIS, but the mine was not expected to produce appreciable amounts of water, so no impacts were predicted. Increased flow (compared to historic mining flows) from the underground mine (15 gpm) contained enough arsenic that treatment is required prior to discharge. Arsenic was noted in tailings leachate from the batch extraction tests, but no tests were conducted on mine workings walls. Acid

drainage, which was predicted as being a potential issue in 1986, has not been an issue so far. Therefore, the hydrologic prediction that there would not be much water in the underground workings was not accurate. Arsenic was not identified as a constituent of concern in mine drainage, in part because no geochemical characterization tests were conducted on waste rock or ore.

6.3.16. STILLWATER, MONTANA

The Stillwater Mine, owned by Stillwater Mining Company, has been in operation since 1986. The primary commodities mined are platinum group minerals from underground mining, using flotation processing methods. It disturbs 255 acres on private and Custer National Forest lands in U.S. Forest Service Region 1. It has a current financial assurance amount of $7.8 million.

6.3.16.1. WATER QUALITY PREDICTIONS SUMMARY

The Custer National Forest and Montana Department of Environmental Quality (formerly Department of State Lands) were the lead agencies for NEPA and MEPA actions at the Stillwater Mine. NEPA was required for the new project to be permitted, and an EIS was completed in 1985. In 1992 an EIS was conducted for a mine expansion and in 1998 an EIS was conducted for a new tailings disposal facility and revised waste management. The following sections summarize the pertinent water quality information in the NEPA documents reviewed.

1985 EIS

According to the 1985 EIS, the original intrusion contained iron, nickel, chromium, copper and platinum-group (sulfide) minerals. Other nickel-copper-chromium deposits are located in the local area. No information is contained in the EIS on geochemical characterization testing or water quality impact potential. The only constituent of concern identified was nitrogen. Mitigation would include lining of the tailings impoundment with 36-mil hypalon synthetic liner to prevent seepage from reaching the Stillwater River. Only nitrogen compounds were expected to affect groundwater quality. Even under most severe conditions (high flow and high nitrate concentrations in pond seepage and low flow and high nitrate concentrations in river) excess algal growth in the river was not expected to occur. Additional nitrogen compounds would not influence algae growth because of the low phosphorous concentrations in the river. Stillwater River was not predicted to be influenced by seepage from dewatering of the underground workings.

1992 EIS

Geochemical characterization consisted of static testing of ore and waste materials. The EIS proposed to do static and if necessary kinetic testing to identify potential for acid production and metals leaching. Constituents of concern identified in ore included lead, cadmium, mercury and zinc, iron, copper, nickel, TDS, sulfate, nitrate, chromium, ammonia and nitrate. Mitigation included lining of the tailings impoundment, reclamation to include a structural cap of waste rock, and reduction in the use of nitrogen-containing explosives. The operation is a zero-discharge facility except for underground workings dewatering discharges, which are percolated to groundwater (land application discharge or LAD).

1998 EIS

According to the 1998 EIS, acid-base accounting, Toxicity Characteristic Leaching Procedure (TCLP), Sequential Saturated Rolling Extraction, and column leach extraction tests were performed, and the HELP model was used to estimate infiltration into waste rock and tailings. ABA test results showed low potential for the waste rock to generate acid.

According to the EIS, the primary mitigation for the new tailings impoundment were an HDPE and clay liner with an seepage collection system and treatment of water from underground workings for nitrogen using denitrification with an anoxic biotreatment cell.

Seepage from the unlined storage pond was predicted to have no significant impact on groundwater quality because of the low permeability of underlying glacial material (project less than 2 gpm seepage). Groundwater in the area is not expected to be impacted. Modeling predicted nitrate concentrations in the Stillwater River from Hertzler LAD water to be 0.70 mg/l, but concentrations are expected to be much lower due to uptake by vegetation, evaporation and high flow in the Stillwater River. Alluvial waters along the Stillwater River are not predicted to be affected, as the Hertzler Tailings Impoundment and LAD are more than one mile from the river.

6.3.16.2. ACTUAL WATER QUALITY CONDITIONS

The 1992 EIS stated that chromium, zinc and to a lesser extent, cadmium, were elevated in well downgradient of the LAD relative to upgradient wells. Increased TDS, sulfate, nitrate and to a lesser extent, chromium and zinc, were thought to reflect the disposal of excess adit water through land application and percolation. According to the 1998 EIS, water discharged from the West Side Adit and East Side Adit between March 1990 and June 1997 exceeded standards (either Montana human life or aquatic standards) for dissolved cadmium, copper, manganese, zinc and total recoverable cadmium, copper and lead. Nitrogen in adit discharge water was much higher than baseline levels. Dissolved chromium regularly exceeded human health standards at all groundwater monitoring sites in the LAD area, and there were slight elevations of sulfate, chloride, phosphorous, cadmium, iron, and zinc observed downgradient of the LAD area**.**

The Stillwater Mine has been collecting surface water and groundwater quality data since 1980 to document the water quality to prior the development of the mine and during on-going mine operations. In 2003, a comprehensive Baseline Water Quality Study (CSP2, 2003) was completed examining the baseline water quality from before mining to present. The results of the study showed that over the approximately 18 years of mine life no noticeable impacts (compliance with Montana non-degradation water quality standards) to water quality in the Stillwater River have occurred due to the operation of the Stillwater Mine. There were no discernable impacts with the exception of increased nitrogen concentrations, which are from mining operations. The increase in concentration averages approximately 0.2 mg/l over the life of the mine with seasonal fluctuations ranging from less than 0.1 mg/l to as high as 0.7 mg/l (the regulatory limit in SMC's MPDES permit is 1.0 mg/l). Stillwater Mining, as part of to Good Neighbor Agreement with local conservation organizations, has agreed to optimize its water treatment and land application discharge operations and remove 90% more nitrogen than is required by its NPDES permit and reduce maximum concentration increases in groundwater to 2.0 mg/l and in the Stillwater River to 0.2 mg/l.

6.3.16.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.21 provides a summary and comparison of potential, predicted and actual water quality information for the Stillwater Mine. The accuracy of the predictions is discussed in this section.

<u>Elevated Concentrations of Nitrate, Metals and Anions in Adit Discharge and Groundwater in the LAD Area:</u>. The 1985 EIS did not include geochemical characterization but did indicate the potential for increased nitrogen concentrations. The 1992 EIS identified lead, cadmium, mercury, zinc, iron, copper, nickel, chromium, TDS, sulfate and nitrogen in ore and waste materials as constituents of concern. The 1992 EIS also noted that increased concentrations of chromium, zinc, cadmium and other constituents were present in groundwater in the LAD area. The 1998 EIS indicated no potential for groundwater impact from land application of adit discharge water, even though increased concentrations had been noted in the 1992 EIS. The 1998 EIS indicated that groundwater being discharged from the underground mine to percolation and LAD exceeded surface water standards for metals and nitrogen, and groundwater at the site had elevated levels of metals and sulfate. However, the 1998 EIS failed to identify that the most likely source for the metals and sulfate was historic tailings, and not current mine operations other than for nitrate. Therefore, many of the constituents with increased concentrations in groundwater in the LAD area had been

identified as constituents of concern, but the potential for impacts to groundwater from the LAD system was underestimated.

Table 6.21. Stillwater, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings and Waste Rock	• 1985 EIS; no potential for acid drainage or other contaminants except nitrogen • 1992 EIS; potential for Pb, Cd, Hg, Zn, Fe, Cu, Ni, Cr, TDS, Sulfate, nitrogen compounds • 1998 EIS: no potential for acid drainage or metals identified: potential for nitrogen identified	• 1985 EIS; line tailings impoundment • 1992 EIS; line tailings, cap waste rock, reduce explosives usage • 1998 EIS: line tailings impoundment	• 1985 EIS; nitrogen will increase in groundwater but no impacts to surface water quality • 1992 EIS; no impacts to water quality predicted 1998 EIS: no impacts to water quality predicted	1985 – 2004: No discernible impacts to surface water or groundwater other than nitrogen (below standards)
	Discharge Water from Underground Workings	1998 EIS: Water discharged from underground workings exceeds standards for Cd, Cu, Mn, Zn, Pb with high levels of nitrogen. LAD discharge contains elevated levels of Cr, SO_4, Cl, P, Cd, Fe, Zn	• 1998 EIS: water treatment to reduce nitrogen and land application discharge at agronomic rates for nitrogen uptake	• 1998 EIS: Groundwater quality not expected to be diminished and surface water would not be affected	• Adit water (1990 - 1997) exceeded Montana standards for Cd, Cu, Pb, Mn, Zn; N concentrations higher than baseline. Groundwater downgradient of LAD had regular exceedences of Cr and slight elevations of SO_4, Cl, P, Cd, Fe, Zn. • Increases in the Stillwater River of N, up to 0.7 mg/l (std = 1.0 mg/l).

<u>Increases in Nitrate Concentrations Above Baseline Values in Stillwater River:</u> A Baseline Water Quality Review which examined the groundwater and surface water quality at the mine found that no detectable impacts to surface water quality have occurred during the 20+ year mine life other than increases in nitrogen typically 80% below (90% below from 2000-2005) the narrative standard of 1.0 mg/l. The increased concentrations are related to mining activity. The potential for movement of nitrate toward the river was acknowledged, but, nitrate and ammonia concentrations from the LAD were not expected to affect the Stillwater River. Modeling predicted nitrate nitrogen concentrations from the LAD to be 0.70 mg/l or lower in the river, due to uptake by vegetation, evaporation and high flow in the Stillwater River. Therefore, the impacts of nitrate (above baseline values but below standards) to the Stillwater River were accurately predicted.

6.3.17. ZORTMAN AND LANDUSKY, MONTANA

The Zortman and Landusky mines (initially two separate mines), owned by Pegasus Gold Co., started operation in 1979. The operations were suspended in 1997, followed by company bankruptcy and mine closure in 1998. The primary commodities mined were gold and silver from numerous open pits using cyanide heap leach processing methods. It disturbs 1,215 acres on private and BLM lands. It had a financial assurance amount of $70.5 million when Pegasus went bankrupt.

6.3.17.1. WATER QUALITY PREDICTIONS SUMMARY

The Bureau of Land Management and the Montana Department of Environmental quality (formerly Department of State Lands) were the lead agencies for NEPA and MEPA actions at the Zortman and Landusky mines. NEPA and MEPA were required for the new project to be permitted, and an EIS was completed for both mines in 1979. In 1993 an EA for modified operating and reclamation was performed, and in 1996 an EIS for a major expansion of the Zortman Mine, along with modified reclamation plans for both mines, was performed. Subsequent to Pegasus's bankruptcy, a SEIS was conducted in 2001 to address reclamation and closure issues. The following sections summarize the water quality information in the NEPA documents reviewed.

1979 EIS

According to the EIS, oxidation (on both properties) generally persists to the levels of the deepest workings on the property, which are 500 ft bgs. No geochemical characterization tests were conducted, and the only constituents of concern identified were cyanide and cyanide complexes. The potential for a lining failure was acknowledged, in either the heap or process water pads, which would release an unknown amount of solution to the groundwater. In this case, the presence of significant amounts of heavy metal ions in the seepage would be of a potentially great concern. For surface water, the major concerns were identified as sedimentation and chemical contamination from potential leaks or overflows of leach pad or pregnant and barren ponds. However, no measurable cumulative impact was expected to surface water from either project after mitigation (berms, ditches and impermeable barriers) are in place. The potential for acid drainage development was expected to be low because only oxide ore would be mined.

Mitigation were directed towards potential cyanide leach solution leakage and stormwater management. A groundwater monitoring program was proposed, where any contaminated groundwater would be pumped and piped for containment and neutralization in either the barren pond or and emergency storage pond until the source of the leak is detected and repaired. However, because of the utilization of both membrane and clay liners, it was not anticipated that either operation would have a significant effect on groundwater quality during normal operations. The utilization of berms, ditches and impermeable barriers was expected to prevent deterioration of surface water from the waste ponds. A cumulative effect on the groundwater was predicted from infiltration from both pits. The impact, however, was expected to be small due to the small area proposed for mining. No water was expected to accumulate in pits because the pit floors were proposed to be sloped and graded to prevent the formation of ponds.

1990/91 EA

Static tests were conducted as part of the 1990 EA to assess the potential for acid rock drainage. The sample results showed some rock units had net acid generating potential and some units had net neutralizing potential. The study used the composite of all rock samples to conclude that widespread development of ARD was not likely. As mitigation, the operator's plan stated that any high sulfide waste rock would be placed on the leach pad instead of the waste rock dump. In 1993 BLM issued a noncompliance with ZMI for not following this mitigation and ordered waste rock disposal in the Mill Gulch waste rock dump to cease.

The main water quality issue in this EA was the post-closure retention of high cyanide concentrations in the spent ore. A cyanide degradation study was required as part of the EA. The study concluded that cyanide concentrations would rapidly degrade after leaching and that only minimal rinsing would be necessary. This study turned out to be correct regarding cyanide levels, but did not address the high nitrate concentrations left in the heap effluent from the degradation of cyanide.

1993 EA

According to the EA, iron sulfides including pyrite, pyrrhotite and marcasite were identified in the ore. Geochemical characterization tests performed include paste pH, total sulfur, ABA, leachate extraction tests and long-term field-based leachate extractions. Constituents of concern identified included cadmium, fluoride, sulfate, zinc, low pH, nitrate and arsenic. Major ores being mined contained both oxide and sulfide rock.

The EA identified mitigation including properly engineered caps over reclaimed dumps and heap leach pads. Pump-back systems were proposed to reduce impacts to groundwater by collecting acidified water below Sullivan Park dike and routing it into the pump-back system. A water treatment plant was required to be constructed at the Zortman Mine to treat mine drainage from both mines. The treatment plant was brought online in 1994. Slurry cutoff walls below the dike were proposed to reduce the volume of acidic water bypassing the contingency pond. Perforation of the leach pad liners would be delayed until leach pad seepage meets water quality standards. Diversion structures were designed to withstand 6-inch, 100-year, 24-hour storm events. Leach pad underdrains will capture water that is pumped to the contingency pond and not discharged to surface waters but directed to the processing circuit.

1996 EIS

Geochemical characterization tests performed include total sulfur, paste pH, ABA, kinetic testing (both long term and short term) and humidity cell tests for ore and waste rock, and cyanide speciation analysis. The HELP model was used to predict infiltration rates. Constituents of concern identified included cyanides, sulfate, TDS, nitrate and metals. Static tests performed on Zortman and Landusky ores showed a strong potential to generate acid. For both mine sites, waste samples having negative NNP's were considered potentially acid generating. At Landusky, short-term increases in TDS, sulfate and metals concentrations were predicted to occur at Sullivan Creek, Mill Gulch and Montana Gulch due to the lack of diluting water, but the loads were expected to be reduced rapidly.

Mitigation identified included segregating acid-generating waste from non-acid generating waste and using a combination of "water barrier" and "water balance" reclamation covers. Most of the historic mine workings would be removed by extended mining of Zortman pits. Old adits would be bulkheaded where exposed in the pits to minimize oxygen flow and discharge of transient water. A water quality improvement plan would be implemented. Capture systems, cutoff walls and recovery wells would be used to intercept poor quality surface water. Existing waste rock dumps would be removed and used as backfill material for pits. The Zortman pit complex was proposed to be backfilled with waste rock to an elevation necessary to drain freely into Ruby Gulch and Alder Spur, thereby reducing the potential for groundwater discharge to the north. Water treatment of collected groundwater and surface water for cyanide, nitrate, acid drainage, metals and other constituents would be implemented as required. The EIS predicted that the volume of acid drainage that would need water treatment over the next 20 years would be between 211 and 419 gpm. In 2005 the Zortman and Landusky water treatment plants treated at an annualized average of 490 gpm.

2001 EIS

According to the 2001 supplemental EIS, iron and iron/arsenic sulfides are present in the igneous intrusion responsible for the orebody. Carbonates exist in the area, but not in the ore deposit itself. Additional geochemical characterization tests were performed including paste pH, paste TDS, and ABA. Constituents of concern identified included sulfate, low pH, iron, aluminum, zinc, arsenic, copper, cadmium, cyanide and nitrate. It is expected that eventually most sources at the site (leach pads, waste rock, pits) have significant potential to generate acid drainage and to leach metals and other contaminants, although some units are not presently generating acid drainage. Water quality was generally expected to become acidic and have increased sulfate concentrations. The potential for infiltration of contaminated water to impact deeper groundwater was considered low due to surface water/groundwater interaction (groundwater losing to surface water in all cases) at higher elevations.

Mitigation included consolidation and backfilling of acid-generating waste, water barrier liners, water balance reclamation covers and revegetation to significantly reduce impacts to groundwater and surface water quality in the various drainages. Water treatment plants (lime precipitation with additional arsenic treatment) at the Zortman and Landusky mines would be used to treat water in perpetuity. Short-term biological treatment was also proposed to reduce cyanide, selenium and nitrate levels for leach pad waters being discharged.

According to the EIS, downgradient water quality predictions showed a wide range of possible concentrations. Therefore, continued monitoring and provisions for supplemental capture and treatment were proposed to prevent significant impacts to water quality. Spent ore on the L87/91 pad is expected to be a significant source of acid generation in the future. Water quality impacts in the northern drainages were predicted to increase if the acid generating material from the L87/91 pad was placed as pit backfill in the headwaters of these drainages. Concentrations of most contaminants from the Landusky Mine were predicted to increase over time. Pit backfilling was expected to increase loads of contaminants in the short term due to the disturbance of acid-generating material, the re-establishment of flowpaths and mobilization of soluble oxidation products (metal-sulfate salts).

6.3.17.2. ACTUAL WATER QUALITY CONDITIONS

1993 EA

Acid has developed from waste rock dumps and ore heap retaining dikes. The flow of acidic water from the toe of the dump and observed venting of sulfurous steam from portions of the dump are manifestations of the sulfide oxidation reactions occurring within the dump. Mill Gulch waste dump has generated acid drainage with pH periodically dropping as low as 3.9. Based on field inspections, BLM and DSL found that approved operating and reclamation plans were not preventing acid drainage. Mill Gulch and upper Sullivan Creek have become acidic as a result of pyrite oxidation in waste rock placed in Mill Gulch Waste Dump, the Sullivan Park dike, and possibly places within the excavated foundation of the 1991 leach pad. Surface water monitoring sites in Sullivan Creek were impacted by acid drainage from the 1991 leach pad, with pH between values between 2.6 and 2.8. Groundwater samples downstream of the Sullivan Park dike indicate that sulfate concentrations in the alluvial groundwater near the facility have increased.

1996 EIS

Acid drainage is currently being generated from pit walls and floors, leach pads and pad foundations, and waste rock piles.

2001 EIS

Acid drainage with metals, metalloids, nitrate and cyanide is common in groundwater at the site and is impacting surface water quality. Capture and treatment of discharges is effective at reducing discharges to below regulatory standards except for arsenic (treatment method is effective but was not always employed by Pegasus).

Recent Water Quality Monitoring Data

Recent (through 2005) surface water quality monitoring data from Montana DEQ indicates the 2001 EIS was correct in identifying mitigation and improving groundwater quality and protecting surface water quality. The notable exception has been in Swift Gulch where surface water quality has worsened, with higher sulfate and metals concentrations. Characterization of the source of Swift Gulch contamination has been difficult and has made identification of potential mitigation measures problematic.

6.3.17.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.22 provides a summary and comparison of potential, predicted and actual water quality information for the Zortman and Landusky mines. The accuracy of the predictions is discussed in this section.

Table 6.22. Zortman and Landusky, MT, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Heap Leach Piles, Open Pit, and Waste Rock Dumps	• 1979 EIS: only oxide ore and no potential identified other than cyanide • 1993 EA: potential for impacts from acid drainage including pH, sulfate, Cd, F, Zn, As, and nitrate. • 1996 EIS: strong potential to generate acid drainage and high TDS, sulfate and metals values • 2001 EIS: high potential to generate acid drainage with pH, sulfate, metals, metalloids, cyanide and nitrate.	• 1979 EIS: only oxide ore to be mined; stormwater controls and liners to prevent cyanide seepage • 1993 EA: reclamation caps (water barrier); groundwater capture and treatment for acid drainage and cyanide, stormwater controls. • 1996 EIS: waste segregation; water balance and water barrier reclamation covers; groundwater and surface water capture and treatment for cyanide, nitrate, acid drainage, metals and other contaminants • 2001 EIS: waste consolidation; reclamation covers, water capture and perpetual treatment	• 1979 EIS: no water quality impacts predicted • 1993 EA: no additional water quality impacts predicted • 1996 EIS: reduced water quality impacts predicted • 2001 EIS: Contaminants to increase over time but surface water quality expected to meet standards. Concentrations of most contaminants from the Landusky Mine are going to increase over time. Pit backfill expected to increase loads of contaminants in the short term due to the disturbance of acid generating material, the re-establishment of flowpaths and mobilization of 'soluble oxidation products'	1993 EA: acid drainage from waste rock dumps and heap leach retaining dikes. Surface water impacted by acid drainage with pH 2.6-2.8. Increased sulfate in groundwater • 1996 EIS: multiple 100+-yr storm events; extensive groundwater and surface water contamination with acid drainage and metals/metalloids, nitrate, cyanides • 2001 EIS: acid drainage with metals, metalloids, nitrate, cyanide common throughout groundwater and in surface water

<u>Low pH and elevated sulfate concentrations in surface water and groundwater</u>: The 1979 EIS indicated no potential for contaminants other than cyanide, based only on oxide ore being mined. The potential for development of acid drainage and groundwater and surface water impacts from acid drainage was not acknowledged in the 1997 EIS. The 1993 EA identified the potential for impacts from acid drainage, sulfate, metals, arsenic and nitrate. Acid drainage from waste rock dumps and heap leach retaining dikes was already impacting groundwater and surface water, but no additional water quality impacts were predicted as a result of capture and treatment. The 1996 EIS indicated strong potential for acid drainage from waste rock and high TDS, sulfate and metals values. Multiple 100+-year storm events led to impacts to surface water and groundwater from acid drainage associated with both waste rock both in dumps and used as leach pad base material. Reduced impacts on water quality were predicted. The 2001 EIS

indicated a high potential to generate acid drainage from waste rock with pH, sulfate, metals and metalloids along with cyanide and nitrate. Metals and metalloids, nitrate and cyanide are common in groundwater and surface water, and contaminants were expected to increase over time; however, surface water quality was expected to be protected.

6.3.18. FLORIDA CANYON, NEVADA

The Florida Canyon Mine, owned by Florida Canyon Mining Company (parent company was formerly Pegasus Gold and now Apollo Gold), has been in operation since 1986. The primary commodities mined are gold and silver from open pit mining and heap leach processing operations. It disturbs 2,149 acres on BLM land. It has a current financial assurance amount of $16.9 million.

6.3.18.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EA was completed in 1986 (not reviewed). In 1995 an EA was conducted for a mine expansion (not reviewed), in 1997 an EIS was conducted for a mine expansion and reclamation, and another expansion EIS was completed in 1999 (not reviewed). The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1997 EIS

According to the 1997 EIS, old mineralization is associated with quartz-veining as auriferous pyrite and free gold. Static testing (ABA), whole rock analysis, short term leach testing (MWMP), kinetic testing (humidity cell and column leach testing) and petrographic analyses were performed. Constituents of concern identified in whole rock and MWMP tests included aluminum, arsenic, cadmium, iron, lead, mercury, antimony, thallium and total dissolved solids (TDS). Static tests showed that 41.5% of the rock had the potential to produce acid and an additional 36.2% of the whole rock had uncertain potential to produce acid. According to the EIS, the modified Sobek method was used to fine-tune the estimate. The result was that only 0.2% of mined rock was identified as having potential to generate acid drainage. Kinetic tests were inconclusive but tended to show a low acid generation potential. However, two of the 14 samples showed acid generating potential. MWMP tests also showed the potential for leaching aluminum, arsenic and iron. HELP, OPUS and UNSAT2 were used to model waste rock seepage.

The EIS characterized baseline groundwater quality; in some wells the EIS claims that concentrations already exceeded drinking water standards for arsenic, aluminum, chloride, manganese, sulfate, TDS, fluoride, and nickel. According to the EIS, even though these samples were taken just downgradient of the heap and pit eight years after the mine commenced construction, the results were attributed to different water quality in different aquifers rather than mining activities. However, the EIS also mentions that groundwater may be impacted by seepage from the heap leach facility, waste rock dumps and by the release of constituents from the pit backfill material. The potential was recognized for dissolution of constituents from the backfill to degrade groundwater quality. No information was presented on surface water quality impact potential or pit water impact potential.

According to the EIS, mitigation consisted of segregating and disposing of potentially acid generating materials within the waste rock dumps. The heap leach facility will be designed as a zero discharge facility and employ a leak detection system. Partial backfilling of the open pit above the water table will eliminate the formation of a pit lake. No impacts to ground water quality were expected as a result of backfilling of the pit with waste rock. Water quality impacts from waste rock dumps were not expected due to low seepage rate, low acid generation potential, natural attenuation properties of alluvium, depth to groundwater, and the waste rock management plan. Contamination of groundwater by leach solution was not expected.

6.3.18.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring data were obtained from the Nevada Department of Environmental Protection (NDEP) for the period 1999 to 2003. Twenty-four groundwater monitoring locations are noted, although not all are in use. No surface water monitoring locations were noted. Information was available on baseline water quality conditions and water quality violations.

Following the 1997 EIS, there were numerous water quality impacts. One monitoring well had elevated concentrations of cyanide (WAD CN = 0.225 mg/l) and other constituents (chloride, mercury, nitrate, and TDS) in groundwater beginning in 2000, suggesting contamination of groundwater with cyanide leach solutions. Following actions taken to address deficiencies in the heap leach pad leak detection pump back system, lower elevations of constituents were noted, although mercury concentrations still exceeds standards. A Notice of Violation was issued for using higher pumping rates than those for which the system had been designed.

Other groundwater monitoring wells on the site showed exceedences of drinking water standards for aluminum, arsenic, cadmium, chloride, iron, manganese, nickel and TDS.

6.3.18.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.23 provides a summary and comparison of potential, predicted and actual water quality information for the Florida Canyon Mine. The accuracy of the predictions is discussed in this section.

Table 6.23. Florida Canyon, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Leach Pads	1997 EIS: • Seepage from the heap leach facility. • Background water quality indicates natural exceedences.	1997 EIS: Facility design to prevent groundwater impacts (zero discharge with leak detection with pumpback of leaks if detected	1997 EIS: No impacts to groundwater predicted	WQ Monitoring: Contamination of groundwater with cyanide and other constituents noted and partially mitigated with leak pumpback system
	Waste Rock, Open Pit, or baseline conditions	1997 EIS: Water quality would be same as pre-mining (background water quality indicates natural exceedences).	1997 EIS: • Backfill pit to prevent formation of pit lake. • Segregation/disposal of PAG rock in the waste rock dumps	1997 EIS: No impacts to groundwater predicted.	WQ Monitoring: Exceedences of drinking water standards noted in various monitoring wells, which could be attributed to waste rock and open pit leachate or baseline conditions.

<u>Contamination of Groundwater by Seepage from the Leach Pad:</u> Groundwater in at least one well has been impacted by cyanide, mercury, chloride, nitrate and TDS from heap pad leachate. Short-term leach tests results were elevated (above drinking water standards) for aluminum, arsenic, iron, lead, mercury, thallium, and TDS, so this test was predictive for mercury and TDS. The EIS noted that there was the potential for groundwater quality impacts by seepage from the heap leach facility, waste rock dumps, and by release of constituents from the pit backfill material.

The heap leach facility was designed as a zero-discharge operation with a leak-detection system, and contamination of groundwater by leach solution was not expected. Therefore, the potential groundwater quality forecast was correct, and the post-mitigation (predicted) groundwater quality impacts were incorrect. The assumption/prediction that leach pad mitigation (liner and leak detection system) would be effective in preventing groundwater contamination was inaccurate.

Elevated Concentrations of Metals and Sulfate in Groundwater: The possible causes of the observed exceedences are currently not known but include elevated background concentrations, seepage from the waste rock dumps, and infiltration from the open pit. The constituents that exceed concentrations in groundwater (aluminum, arsenic, cadmium, chloride, iron, manganese, nickel, TDS) are very similar to those exceeding standards in the MWMP (short-term leach) test (aluminum, arsenic, iron, lead, mercury, thallium, TDS). Therefore, the short-term leach tests were predictive in identifying constituents that would be elevated in groundwater, regardless of the cause.

6.3.19. JERRITT CANYON, NEVADA

The Jerritt Canyon Mine, owned currently by Queenstake Resources, has been in operation since 1980. The primary commodities mined are gold and silver from underground and open pit mining and heap and vat leach processing operations. It disturbs 3,411 acres on Humboldt-Toiyabe National Forest in U.S. Forest Service Region 4. It has a current financial assurance amount of $7.1 million.

6.3.19.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EIS was completed in 1980. In 1991, an EA was completed in support of an increase in the height and an expansion of the seepage collection system of the tailings impoundment. In 1994 another EIS was conducted for a mine expansion. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1980 EIS

According to the 1980 EIS, results from short-term leach tests conducted on waste rock samples showed only minimal potential for leaching of heavy metals and other toxic substances to surface and groundwater. However, suspended solids from erosion were expected to increase. No other information was provided on tailings testing or potential for water quality impacts in the 1980 EIS.

According to the EIS, mitigation will consist of locating the mill and tailings impoundment in the headwaters of a small watershed, and this was expected to have negligible effects on water quality. The tailings impoundment will be lined to provide an impervious barrier to vertical movement. Horizontal seepage of liquids will be controlled by the dam embankment design. Diversion ditches will direct flow around the mine pit and back into natural drainages (run on controls). Groundwater flowing into the pits will be used for dust control, and at times, excess water may be discharged to Jerritt Canyon.

The EIS included information on background surface water sampling stations that showed elevated nitrate concentrations, anomalous values for zinc, and exceedences of the drinking water standard for mercury and chromium.

1991 EA

This EA was written to analyze a 50-foot height increase to the tailings impoundment and to install a seepage remediation system. There were no geochemical tests performed on tailings material.

Even though the EA analyzed the new seepage remediation system, it did not provide details of the ongoing contamination (see Section 6.3.19.2), other than to indicate that pre-mining background water quality was within standards and that a plume of salt extended up to 1000 feet from the tailings impoundment. The EA indicated that concentrations of constituents seeping from the tails were relatively low. It indicated the six pumpback wells previously installed were not sufficient to prevent migration away from the impoundment.

1994 EIS

According to the EIS, geochemical testing on waste rock included static acid-base accounting, humidity cell, column leaching and short-term leach (MWMP) tests. Constituents of concern identified from waste rock leach tests included arsenic, selenium, nitrate and sulfate. Waste rock from the Roberts Mountain and Hanson Creek formations had low acid-generation potential. Waste rock from the Snow Canyon formation had moderate potential to generate acid. Waste rock from the unoxidized, strongly altered intrusive rock was acid-forming but would make up less than 2% of the waste rock in the proposed waste rock dumps. Groundwater quality would be potentially affected if waste rock and pits generate acid and mobilize metals and other compounds. Spring and seep water quality may be affected by contact with waste rock dumps, or by contact with pit walls. There is potential for acid drainage from waste rock, ore stockpiles or pits to affect waterways, and a potential increase in sedimentation resulting from roads, pits and waste rock dumps.

According to the EIS, mitigation would consist of the Saval, Steer, Burns Basin pits (proposed) lying above the regional groundwater table and not accumulating water. The New Deep deposit will be mined using underground techniques, so no pit lake will form. No existing pit has encountered the regional groundwater table. Acid mine drainage will be mitigated with selective handling and isolation of acid forming waste rock and capping, contouring, or drainage control to reduce infiltration. No impacts to surface or ground water were predicted due to the implementation of the waste rock characterization and handling program and plugging of the underground workings.

6.3.19.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring data was obtained from the Nevada Department of Environmental Protection (NDEP) for 1997-1998 and 2000- 2003. Twenty-one surface water monitoring locations and seven groundwater monitoring locations were identified. In addition, one Notice of Violation (NOV) was identified.

The records showed that following the 1980 EIS and 1994 EIS, water quality impacts occurred at the site including the following:

- A Finding of Alleged Violation (FOAV) was issued in 1991 due to a cyanide plume in the groundwater, caused by seepage from the tailings impoundment. A seepage collection system was installed to pump tailings seepage back to the tailings facility.
- Groundwater monitoring wells downgradient of the tailings impoundment showed exceedences for chloride (chloride and total dissolved solids (TDS), with values peaking at 30,000 mg/l (TDS) and 12,000 mg/l chloride in well GW-9. Exceedences of over times federal drinking water standards were common for these constituents, with exceedences of over 10 times standards occurring constantly between 1993 and 2004. Exceedences of federal arsenic and sulfate drinking water standards were also occasionally noted. The tailings impoundment is being gradually evaporated to eliminate seepage.
- Surface monitoring points in drainages below waste rock dumps on Burns Creek, Mill Creek, Jerritt Creek, Snow Creek and Sheep Creek showed exceedences of secondary federal drinking water standards for TDS and sulfate. One surface monitoring site showed a steady increase in TDS and sulfate concentrations from 2001-2004, with exceedences of over 10 times standards for both by early 2004. The exceedences were most likely related to the waste rock disposal pile.

6.3.19.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.24 provides a summary and comparison of potential, predicted and actual water quality information for the Jerritt Canyon mine. The accuracy of the predictions is discussed in this section.

Table 6.24. Jerritt Canyon, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater and Surface Water	Tailings	• 1980 EIS: No information provided for groundwater. Possibility of release of toxic materials to streams due to breakage of the tailings pipeline.	• 1980 EIS: Tailings located in headwaters of small water shed will protect water quality • 1980 EIS: Facility design to prevent groundwater impacts o Tailings disposal pond will be lined o Horizontal seepage controlled by embankment design.	• 1980 EIS: No impacts predicted • 1991 EA: Six pumpback wells are not effective at preventing migration of plume from impoundment	Water Quality Monitoring • 1991: Cyanide plume detected from tailings pond and seepage collection installed • 1993-2004: Groundwater monitoring wells downgradient of the tailing impoundment show exceedences for Cl and TDS consistently from 1993 –2004
	Waste Rock	• 1980 EIS: Minimum potential for some leaching of some heavy metals and other toxic substances in the waste rock into surface and ground water • 1994 EIS: Groundwater and surface water quality may be affected by acid drainage and other constituents in waste rock	• 1980 EIS: No information provided • 1994 EIS: Waste rock mitigation include: o Segregation and blending of PAG waste rock. o 1994 EIS: Capping, contouring and drainage controls o 1994 EIS: Waste rock characterization and handling (segregation, cap, contour, drainage) program	• 1980 EIS: Minimum impacts predicted • 1994 EIS: No impacts to groundwater or surface water predicted	Water Quality Monitoring • 2001-2004: Surface monitoring shows a steady increase in TDS and SO_4 concentrations downstream from waste rock piles from 2001-2004 with most recent data indicating exceedences of standards by 10 times
	Open Pit	• 1980 EIS: No information • 1994 EIS: Groundwater and surface water quality may be affected by acid drainage and other constituents in pit walls	1980 EIS: Divert surface water flow around pit and groundwater from pit used for dust control or discharged	• 1980 EIS: No impacts predicted • 1994 EIS: No pit lakes predicted to form	

<u>Cyanide Plume and Exceedences of Chloride, TDS, Sulfate and Arsenic in Groundwater from Tailings Impoundment Leakage</u>: The tailings generated from the vat leach operation were responsible for creation of a cyanide plume in groundwater. Exceedences of chloride, TDS, arsenic and sulfate were also observed in wells downgradient of the tailings impoundment. Geochemical characterization in the 1994 EIS focused on the waste rock and noted the potential for leaching of arsenic, selenium, nitrate and sulfate. However, no geochemical testing was performed on tailings material. No information on potential (pre-mitigation) groundwater impacts from tailings was noted, but post-mitigation (related to waste rock and underground mine backfilling and sealing) groundwater quality was predicted to

be good. The only potential impact from tailings was the possibility of release of toxic materials to streams due to breakage of the tailings pipeline. The tailings impoundment was lined and had seepage control features, but these were not adequate to prevent groundwater contamination. Therefore, predictions about the impact of tailings on groundwater were non-existent, and the mitigation for the tailings system failed.

Impact of Waste Rock on Surface Water Quality: Exceedences of sulfate and TDS (by over 10 times the standard) were observed in surface water downstream/gradient of the waste rock piles. Acid-base accounting and short-term leach testing performed on waste rock showed moderate potential for acid drainage and minimal potential for leaching of arsenic, selenium, nitrate, and sulfate. Potential surface water impacts from waste rock were noted in the EISs. However, no impacts to surface water or groundwater were predicted post-mitigation due to the implementation of the waste rock characterization and handling program. Therefore, the potential (pre-mitigation) forecasts were more accurate than the post-mitigation predictions, and the mitigation and management approaches were not successful in preventing surface water impacts from waste rock. Geochemical characterization was able to predict the leaching of sulfate from waste rock, but the impact was larger (>10 times standards) than the "minimal" leaching predicted.

6.3.20. LONE TREE, NEVADA

The Lone Tree Mine, owned by Newmont Mining Company, has been in operation since 1991. The primary commodities mined are gold and silver from open pit mining and heap and vat leach processing operations. It disturbs 2,691 acres and is permitted to disturb 3,547 on both private land and BLM land. It has a current financial assurance amount of $8.4 million.

6.3.20.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was not originally required for the new project in 1991 because it was located on private land. NEPA was required for mine expansion onto public land, and an EIS was completed in 1996. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1996 EIS

Geochemical characterization consisted of static (ABA), kinetic (humidity cell tests), and short-term leach (MWMP) tests and a mixing experiment using acid leachate from Lone Tree rocks and Wayne Zone groundwater. Modeling included water quantity and water quality using MINEDW to predict three-dimensional groundwater flow, and hydrogeochemical modeling of pit lake water by PTI (proprietary). Constituents of concern identified included arsenic, iron, sulfate and total dissolved solids (mine discharge water); antimony, arsenic, cadmium, nickel, fluoride, and sulfate (pit lake); and arsenic, copper, cyanide, iron and sulfate (tailings).

Although static testing indicated that tailings were potentially acid generating, kinetic testing indicated they were not. Sulfides were reported to be encapsulated in silica; humidity cells tests on overburden suggested that silicate buffering would be important. The contaminant leaching potential was predicted to be moderate to high.

Groundwater **-** Pit lake water was predicted to mix with groundwater after steady state groundwater levels are reached; due to natural attenuation, no groundwater exceedences were expected.

Surface Water - Water pumped from the ground and discharged into the Humboldt River is generally of good quality, except for recently increased concentrations of arsenic, iron and sulfate in mine discharge water (Draft EIS). The Final EIS stated that iron, copper and lead exceeded aquatic life criteria in mine discharge water.

Pit Lake - Pit lake water quality was predicted to be acidic and exceed the arsenic standard initially but become neutral after 10 years and not exceed standards for arsenic after that time; cadmium concentrations were predicted to exceed drinking water standards for one year; nickel, fluoride, and antimony for over 25 years; and sulfate until 10 years. Nickel and fluoride concentrations were predicted to exceed their respective limits by less than 10 times and antimony by over 10 times. In the long term, the pit water was predicted to have exceedences of one to 10 times for aluminum, antimony, arsenic, fluoride, total dissolved solids and pH. The drinking water standard for thallium was predicted to be exceed by over 10 times in long term.

6.3.20.2. ACTUAL WATER QUALITY CONDITIONS

Water monitoring and compliance data for the period 1998-2002 were obtained from the Nevada Department of Environmental Protection (NDEP). There are 16 groundwater monitoring locations (11 monitoring wells and five production wells) at Lone Tree. No information on violations was found.

Possible mine water quality related impacts and exceedences were indicated including the following:

- Mine Water Supply Wells: Production well WW-13 exceeded the secondary standards for fluoride and manganese in 1998 and 2000. Concentrations of both constituents were less than twice the standard.
- Heap leach groundwater monitoring wells: Occasional exceedences of Secondary MCLs were recorded at wells MO15-1A, MO15-2A, MO15-3 3 from 1999-2000 for aluminum, iron, and TDS. Except for an aluminum concentration of 1.05 mg/l (standard is 0.05-0.2 mg/l), all concentrations were less than twice the drinking water standard.
- Tailings monitoring wells: Tailings monitoring wells recorded numerous exceedences of secondary drinking water MCLs from 1999-2002. Constituents of concern included fluoride, iron, manganese and TDS. Frequent fluoride SMCL exceedences were recorded from 1999-2001, but the primary MCL (4.0 mg/l) was not exceeded. Some tailings monitoring wells had arsenic concentrations at the level of the new standard (10 µg/l) in 2000 and 2002.
- The tailings impoundment experienced a major leak in November, 2000, but the leak was not detected below the vadose zone.
- Between 1998 and 2002, dewatering water discharged into the Humboldt River exceeded standards frequently for pH, total dissolved solids, fluoride, boron and un-ionized ammonia.

6.3.20.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.25 provides a summary and comparison of potential, predicted and actual water quality information for the Lone Tree mine. The accuracy of the predictions is discussed in this section.

<u>Exceedence of Arsenic and Secondary Drinking Water Standards in Groundwater:</u> Because information on background groundwater quality was not obtained, it is unknown if the observed exceedences in groundwater relate to seepage from facilities or background conditions. Heap leach monitoring wells had exceedences of arsenic, aluminum, iron and TDS. Tailings monitoring wells had exceedences of arsenic, fluoride, iron, manganese and TDS. Potential water quality impacts noted in the EIS included discharge of acid water from overburden, tailings, leach pads and ore stockpiles. Tailings MWMP extract for tailings exceeded drinking water standards for pH, TDS, sulfate, arsenic, copper, iron (all by <10x) and cyanide (>10x). These results did not predict noted exceedences of fluoride or manganese in tailings wells. No acid drainage has occurred to date.

<u>Exceedence of Permit Limits for Dewatering Discharge:</u> More information is needed on NPDES discharge water quality. The EIS predicted that no significant impacts would occur to the Humboldt River after mitigation were performed, which included cooling and treatment of discharge water to remove arsenic.

Table 6.25. Lone Tree, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	MITIGATION	Predicted Impacts	Actual Impact
Groundwater	Heap Leach	1996 EIS: No estimates of potential impacts to water quality	1996 EIS: No specific mitigation provided	1996 EIS: No estimates of predicted water quality	WQ Monitoring: possible exceedences of As, Al, Fe, and TDS
	Tailings	1996 EIS: No potential for acid drainage. Moderate to high potential for As, Cu, CN, Fe, and sulfate	1996 EIS: No specific mitigation provided	1996 EIS: No estimates of predicted water quality	WQ Monitoring: possible exceedences of secondary drinking water MCLs from 1999-2002 for fluoride, iron, manganese, and TDS
	Waste Rock	1996 EIS: No estimates of potential impacts to water quality	1996 EIS: Overburden mixing and segregation	1996 EIS: No estimates of predicted water quality	WQ Monitoring: No exceedences indicated
	Open Pit	1996 EIS: Pit lake water quality acidic initially, but after 10 yr neutral; would exceed standards for As, Cd, Ni, F, Sb (by >10x), Tl (by >10x), and SO_4 at different times	1996 EIS: Diversions to prevent runoff from entering pits	1996 EIS: Groundwater downgradient from mine pit would approach baseline quality of regional groundwater, not expected to exceed MCLs	
Surface Water	Pit Dewatering	1996 EIS: Fe, Cu, and Pb are the only parameters that exceeded aquatic life criteria in mine discharge water	1996 EIS: Affected springs mitigated by: piping in water, drilling into a deeper aquifer, improving existing springs to enhance yield, or developing/improving nearby springs to offset loss. Monitoring	1996 EIS: No significant impacts would occur, but discharge to Humboldt River would increase total dissolved solids and trace elements	Water pumped from the ground and discharged into the Humboldt River Discharge exceeds permit limits for TDS, B, F, pH and NH_3.

6.3.21. ROCHESTER, NEVADA

The Rochester Mine, owned by Coeur Rochester, Inc., has been in operation since 1986, although the site has been mined since the 1860s. The primary commodities mined are gold and silver from open pit mining and heap leach processing operations. It disturbs 1,447 acres on both private land and BLM land. It has a current financial assurance amount of $8.4 million.

6.3.21.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EA was completed in 2001. In 2003 an EA was conducted for a mine expansion. There has never been an EIS completed for this facility, but beginning in 2004 the BLM began preparing a closure EIS. The following sections summarize the water quality predictions made in the NEPA documents.

2001 EA

The 2001 EA considered the Nevada Packard deposit, which was a satellite deposit from the primary Rochester project. Geochemical characterization consisted of acid-base accounting, short-term leach testing (MWMP) and whole rock analysis. Constituents of concern identified included antimony, arsenic, iron, lead, mercury and silver. No predictive modeling was performed. Acid drainage potential was estimated to be low. Rocks in the project area generally have low sulfur content and low neutralizing potential. Only two of 26 acid-base accounting results showed potential to generate acid. Whole rock (ICP) analyses of non-ore and unmineralized rock samples suggested that antimony, arsenic, lead, mercury and silver could produce leachate with elevated concentrations. Short-term leach test (MWMP) results showed that antimony, arsenic, iron and mercury could occur in elevated concentrations in discharge water from the non-ore material.

There was no information in the 2001 EA on potential impacts to groundwater. Due to historic mining in the area, the current site includes abandoned tailings material, waste dumps and leach pads that are likely to have an impact on surface water quality. The water table is 140 feet below the proposed pit bottom, so no pit lake is expected to form. No information on mitigation was provided.

The proposed action was considered unlikely to degrade groundwater resources or further degrade baseline surface water quality, since a part of the proposed action included reclamation of the abandoned pre-Coeur workings.

2003 EA

This was the most recent EA to consider continuing expansions of projects at the Rochester Mine. Reports of earlier testing showed that some of the lithologies above 6,600 feet were substantially acid generating, but no details were provided. Below 6,600, from 10 to 20 percent of the rock was classified as potentially acid generating (PAG), based on acid-base accounting and humidity cell analysis. MWMP tests showed limited metal mobility from non-PAG rock, but test pH values ranged from 4.0 to 6.4. For PAG rock, lead, cadmium, zinc, copper and aluminum concentrations were occasionally high.

The section on potential impacts claimed that the rock was mostly non-PAG, and the surrounding rock would neutralize any acid that may be generated.

Future developments at the Coeur operations could generate long-term impacts to groundwater. The potential for acid rock drainage from the present actions was identified.

6.3.21.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring and compliance data were collected from the Nevada Department of Environmental Quality (NDEP) for the period 2000- 2003. Three surface water monitoring locations and 17 groundwater monitoring locations were noted for the site. The following information on water quality was noted.

- Groundwater monitoring wells downgradient of the Stage I heap leach pad showed exceedences of arsenic, mercury, cadmium, nitrate and WAD cyanide during the period 2000 to 2003.
- Surface water monitoring sites in a spring downgradient of the Stage I heap leach pad showed exceedences of nitrate, lead, cyanide, arsenic, mercury.
- In 2003 NDEP issued Rochester a Finding of Alleged Violation (FOAV) for cyanide exceedences discovered during quarterly monitoring. The violation was issued in response to the discovery of cyanide exceedences in MW-16, a monitoring well screened in the shallow bedrock below the site. Contamination had been previously confined to the alluvium.
- In 1987 a release of process solution from the East Pregnant Pond occurred, causing pregnant solution to run into American Canyon for 12-18 hours at a rate of 5-10 gpm. The United States EPA issued a Notice of Violation to Coeur-Rochester on June 30[t], 1988, for violating the Clean Water Act by discharging pregnant

solution to American Canyon. On July 20th, 1988, NDEP issued an FOAV to Coeur-Rochester for the December 27th, 1987, pregnant solution release. It does not appear that NDEP pursued a monetary settlement.
- In 1998 a broken pipeline resulted in the displacement of 200 tons of ore off the liner, causing 19,400 gallons of process solution containing 45.3 lbs. of cyanide to be released to the environment. Of this, 5,000 gallons of process solution containing 11.7 lbs. of cyanide were discharged off site to American Canyon, an intermittent drainage. A dike was installed in American Canyon to stop solution flows, and affected soil was treated with hydrogen peroxide to degrade cyanide. Displaced ore was moved back to containment.

6.3.21.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.26 provides a summary and comparison of potential, predicted and actual water quality information for the Rochester Mine. The accuracy of the predictions is discussed in this section.

Table 6.26. Rochester, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impact
Groundwater	Heap Leach, Open Pit, Waste Rock	2001 EA: None identified. 2003 EA: Future developments at the Coeur operations could generate long-term impacts to groundwater.	2001 EA: None identified 2003 EA: None identified	2001 EA: The proposed action is considered unlikely to degrade groundwater resources. 2003 EA: Water recharging the groundwater system from infiltration through Rock Disposal Sites not expected to differ from the current groundwater chemistry.	WQ Monitoring: Leaks from the Stage I heap leach pad and the N. Barren pond have resulted in numerous exceedences in groundwater monitoring wells. Exceeding constituents include WAD Cyanide, mercury, cadmium, nitrate and arsenic.
Surface Water and Springs	Heap Leach, Open Pit, Waste Rock	2001 EA: Due to historic mining, current site includes abandoned tailings, waste dumps, and leach pads that are likely to have an impact on t surface water quality. 2003 EA: There is a potential for increased sedimentation from surface disturbance associated with Proposed Action. There is potential for acid drainage from the present actions (2003)	2001 EA: Diversion ditches, as well as other sediment control measures. 2003 EA: Part of the proposed action includes reclamation of the Project, as well as some of the abandoned pre-Coeur mine workings.	2001 EA: Proposed action unlikely to further degrade surface water quality. 2003 EA: The proposed action is unlikely to further degrade baseline water quality, since part of the proposed action includes reclamation of project as well as some abandoned pre-Coeur mine workings.	Contamination of American Canyon (intermittent drainage) by process solution release of Nov. 29th, 1998. Exceedences of nitrate and arsenic in American Canyon Springs from heap leach pad and process solution ponds.

<u>Exceedences of Arsenic, Mercury, Cadmium, Nitrate and Cyanide in Heap Leach Monitoring Wells and Springs</u>: Short-term leach tests and whole rock analysis identified antimony, arsenic, iron, lead, mercury and silver as constituents of concern. Therefore, the potential for arsenic and mercury exceedences was identified, but the cadmium, nitrate and cyanide exceedences were anticipated. There was no information on potential or predicted

impacts to groundwater in the 2001 or 2003 EAs related to the heap leach pad. Therefore, the potential for some of the observed exceedences was noted in the 2001 EA, but the observed exceedences were not predicted to occur in groundwater.

Contamination of American Canyon by Cyanide from Process Solutions: Cyanide was not specifically identified as a constituent of concern, and no potential or predicted impacts from release of process solution to surface water were identified. Therefore, the observed impact to surface water was not predicted in the EAs.

6.3.22. ROUND MOUNTAIN, NEVADA

The Round Mountain Mine, owned by Round Mountain Gold Corporation, has been in operation since 1977. The primary commodities mined are gold and silver from open pit mining and heap leach and vat leach processing operations. It disturbs 4,431acres on private, BLM and Forest Service lands. It has a current financial assurance amount of $41.7 million.

6.3.22.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EA was completed in 1977. In 1987 and 1992, EAs were conducted for a mine expansions, In 1996 an EIS was conducted for further mine expansion. The following section summarizes the water quality predictions made in the only NEPA document obtained and reviewed, the 1996 EIS.

1996 EIS

The primary host rock for mineralization is the Tertiary Round Mountain tuff, in which gold occurs in quartz-carbonate and quartz-pyrite veins. Geochemical characterization consisted of short-term leach testing, static acid-base accounting, kinetic testing and soil attenuation tests. MWMP tests were performed on leach pad offload materials (spent ore), and TCLP and MWMP tests were performed on tailings materials. Net neutralization potential (NNP) and humidity cell tests were performed on pit wall materials. Soil attenuation tests were conducted on leachate from leach offload piles. The effects of mine dewatering and future inflow of water to the pit were predicted using MODFLOW. The pit lake was modeled with CE-THERM-R1 for thermal stratification and overturn, and MINTEQA2 for geochemistry of the pit lake. The Davis-Ritchie model was used to calculate the thickness of the oxidized zone in the wall rock. Groundwater quality was sampled for four different water types, including geothermal waters since 1986, which provides a baseline to compare this project against. The groundwater near the tailings impoundment was not monitored.

There are two facilities in which spent ore will be deposited: leach offload piles and tailings impoundments. Spent ore was identified as having the potential to generate elevated pH values and to leach antimony, arsenic, selenium, and cyanide, and possibly iron, mercury, nickel, nitrate, and fluoride, as well as generating elevated pH values. Geochemical test results suggested that degradation could occur if water were to seep through the leach offload piles and discharge directly into a protected surface water source or groundwater aquifer. The potential was identified for stormwater runoff to mobilize metals and cyanide from the spent ore materials. However, significant impacts to surface water or groundwater quality from leach offload piles was not anticipated due to attenuation in soils.

The potential was identified for carbon-in-leach tailings to leach iron, lead, manganese, TDS and sulfate in concentrations in excess of MCLs; carbon-in-leach tailings, however, would be only 5-10% of total tailings. MWMP test average concentrations on spent ore showed exceedences of over 10 times for arsenic and less than 10 times for antimony, selenium, and cyanide. The pH was also higher than standards. Based on TCLP tests, tailings did not exhibit hazardous properties. If tailings seepage reaches groundwater, there is potential for degradation.

The EIS proposed a zero-discharge tailings facility with a seepage underdrain system designed to alleviate head. If, after cessation of mine processing operations, seepage of tailings solution is still occurring through the underdrain system, the seepage would create a potential impact to groundwater. Any metals and cyanide mobilized by snowmelt or rainfall that runs off the piles or seeps through the piles and later infiltrates the alluvial soils would be rapidly attenuated in the upper soil column, indicating that significant impacts to groundwater from the leach offload piles were not expected.

Excavation of the pit was predicted to expose sulfide minerals and form acid drainage. A 300-foot deep pit lake is expected to form in the pit after dewatering ceases. Forty percent of pit wall samples had potential to generate acid, but modeling indicated that the pit water will not be acidic. In the long run, pit water was predicted to exceed drinking water standards for aluminum, arsenic, fluoride, manganese, mercury, nickel, pH (high), TDS, sulfate and zinc. Modeling of final groundwater levels and flow rates, as well as predicted precipitation and evaporation rates suggested that the pit lake will have no net outflow to either groundwater or surface waters.

6.3.22.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring and compliance data were collected from the Nevada Department of Environmental Protection (NDEP) for the period 1999-2003. Ten groundwater monitoring locations were noted for the site. The following information on water quality was noted:

- Groundwater monitoring wells recorded a number of exceedences of secondary standards for aluminum, fluoride, iron, manganese and TDS. Aluminum exceedences occurred in the pit dewatering water. The other constituents all had exceedences in alluvial wells downgradient of the tailings, heap offload disposal sites and dewatering water. One of the wells had a substantial increase in fluoride concentration. Arsenic exceedences, of both the old and new standards, were very common and are mentioned as a background condition.
- Wells near the tailings also experienced frequent exceedences for antimony and lead. High pH values were also common.
- As noted, the trend in exceedences is for them to be clustered near the tailings and the heap offload sites. A second trend is for the highest concentrations to occur at the shallowest alluvial reaches, which could suggest a surface source. Most of the constituents, but not fluoride, also occur in dewatering water, which is another potential source.

6.3.22.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.27 provides a summary and comparison of potential, predicted and actual water quality information for the Round Mountain Mine. The accuracy of the predictions is discussed in this section.

<u>Exceedences of Aluminum, Antimony, Fluoride, Iron, Lead, Manganese and TDS in Groundwater</u>: The cause of the exceedences in groundwater is not known, but could be due to background groundwater quality and/or discharge from the tailings or heap leach facilities or dewatering water. Because the waste rock was shown to have a significant potential to leach contaminants, the fact that there is relatively little groundwater contamination indicates the mitigation may be working. However, there are trends that cannot be explained by assuming that all exceedences are background. Fluoride is the biggest issue especially since it is a constituent of concern for leaching from the waste rock. It suggests that the baseline water quality was not adequately determined.

Table 6.27. Round Mountain, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings, heap leach offload, or baseline conditions.	Test results suggest some exceedences could occur if water were to seep through leach offload piles, discharge directly to a protected groundwater aquifer. MWMP tests show exceedences of over 10 times for arsenic, and less than 10 times for antimony, selenium and cyanide. pH is also higher than allowed. If, after cessation of mine operations, seepage of tailings is still occurring through underdrain, seepage would create potential impact to groundwater.	Tailings facility designed for zero discharge. Backfill and reclaim the tailings seepage collection pond after underdrain seepage has ceased.	No discharge from pit, so no impact to GW. Significant impacts to ground water quality from leach offload piles not anticipated due to attenuation in soils. Minimal impact to ground water quality from tailings facilities due to management, design. Any metals or cyanide mobilized by snowmelt or rainfall that runs off piles/seeps through piles and infiltrates alluvial soils would be attenuated in upper soil column.	Exceedences of secondary standards for aluminum, fluoride, iron, manganese, pH (high) and TDS and primary drinking water standards for arsenic, antimony, and lead all appear to be related to baseline conditions. No mining-related exceedences are evident.

6.3.23. RUBY HILL, NEVADA

The Ruby Hill Mine, owned by Barrick Goldstrike since its acquisition from Homestake, has been in operation since 1997. Mining ceased and reclamation commenced in 2002, although processing of gold and silver from its cyanide heap leaches continues to this day. It disturbs 696 acres on private lands. It has a current financial assurance amount of $7.1 million. The mine issued a DEIS to reopen and expand its operations in 2005.

6.3.23.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EIS was completed in 1997. The following sections summarize the water quality predictions made in the NEPA documents reviewed.

1997 EIS

The ore is oxide and hosted in limestone, with some sulfides present. The following predictive tests were performed: whole rock analysis static ABA, MWMP, humidity cell and synthetic precipitation leach procedure (EPA method 1312). The average ANP:AGP was 813 for alluvial material and 955 for oxidized limestone samples; the potential for acid generation was considered low. Leach tests indicated there was a moderate potential for contaminant/metals leaching; meteoric water mobility procedure (MWMP) results from alluvial material and oxidized limestone showed occasional drinking water exceedences for aluminum, arsenic, antimony and TDS. EPA method 1312 leach tests showed exceedences for aluminum, arsenic and pH (high).

Modeling indicated low potential for groundwater degradation. Increased erosion was the only noted surface water quality concern. No impacts to surface or ground water were predicted, due to the nature of the rocks, as well as the distance to water. The pit bottom will be above the regional water table, so no pit lake was expected.

6.3.23.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring and compliance data were obtained from the Nevada Department of Environmental Protection (NDEP) for the period 1997-2003, and the 2005 DEIS also summarizes water quality at the site. Nine groundwater monitoring locations were noted for the site.

Only two constituents had substantially high concentrations: arsenic and nitrate. Two wells had high arsenic concentrations, often exceeding MCL values by two to four times; concentrations increased by about 20% between 1996 and 2003. However, the highest concentration occurred upgradient of the mine. Elevated pH values were also common in groundwater wells. Nitrate concentrations frequently approached the MCL in several wells. The 2005 EIS suggested these predated the mine and were due to septic systems.

There were lead exceedences (less than twice the drinking water standard) during the fourth quarter of 1997 and the first quarter of 1998 in monitoring well MW-4, although no problems were recorded after this point. Since the exceedences did not recur, it did not result in any action by NDEP.

6.3.23.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.28 provides a summary and comparison of potential, predicted and actual water quality information for the Ruby Hill Mine. The accuracy of the predictions is discussed in this section.

Table 6.28 Ruby Hill, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impact
Groundwater	Baseline conditions.	Low potential for degradation from leaching of Arsenic and Aluminum, according to the Horizontal Plane Source Model. Partial backfilling of pit (preferred alternative) would increase potential chemical impacts.	Zero discharge heap leach with a leakage detection/collection system; rinsing of heap leach during closure followed by a land application of rinse water.	Contamination of groundwater by leach solution not expected. Cumulative impacts from the waste rock and leach residue are not expected to occur.	None. Any exceedences appear to be related to baseline conditions.

Water quality impacts were not expected and did not occur. Therefore, assuming that the exceedences are related to baseline conditions, the water quality predictions were accurate.

6.3.24. TWIN CREEKS, NEVADA

The Twin Creeks Mine, owned by Newmont Mining Corporation since its acquisition from Santa Fe Mining, is the combination of the Rabbit Creek and Chimney Creek mines, which began operating in around 1988. The primary commodities mined are gold and silver from open pit mining and heap leach, vat leach, and oxide milling processing operations. It disturbs 4,549 acres on private land and 8,898 acres on BLM lands for a total disturbance of 13,447 acres. The current financial assurance amount is not known.

6.3.24.1. WATER QUALITY PREDICTIONS SUMMARY

Initially, the two mines, Chimney Creek and Rabbit Creek, were permitted with EAs. In 1996 an EIS was conducted for a mine expansion, which included combining the two existing mines. The following section summarizes the geochemical characterization, hydrologic analysis and predictions and water quality predictions made in the 1996 EIS.

1996 EIS

Arsenic-mercury mineralization occurs mostly in oxidized ore, but there is some sulfide ore in the South Pit deposit. Sulfide minerals associated with gold mineralization include pyrite, stibnite, realgar and orpiment. Sulfide ore from the Mule Canyon Mine will also be processed at the Twin Creeks Mine.

Waste rock and pit wall rock were analyzed with static (ABA), kinetic (20-wk humidity cell; 46 pit wall rock samples), mineralogy, and short-term leach tests (MWMP). Hydrologic modeling included MINEDW (proprietary) for groundwater dewatering. Mass balance modeling was used to predict the final pit lake elevation. CE-THERM-R1 was used to predict pit evaporation. DE-QUAL-W2 was used for modeling limnologic processes. Geochemical modeling included MINTEQA2 for predicting pit water chemistry and the Davis-Ritchie model for predicting the thickness of the oxidized zone in the pit walls over time.

Based on MWMP leachate results for waste rock, pit wall rock and tailings, and on humidity cell tests for pit wall rock, total dissolved solids, aluminum, antimony, arsenic, beryllium, cadmium, chloride, chromium, copper, iron, lead, manganese, mercury, nickel, nitrate, selenium, silver, sulfate, thallium and zinc were the constituents of concern. Waste rock (based on MWMP tests) leachate could exceed drinking water standards for total dissolved solids, beryllium, cadmium, selenium, zinc (all by 1 – 10 times), and for aluminum, antimony, arsenic, iron, manganese, mercury, nickel, sulfate and thallium (all by >10 times).

The acid generating potential of pit wall rock ranged from a net neutralizing potential (NNP) of -350 to +671t/kt, with an average of +162 t/kt (average is non acid generating). The majority (91%) of rocks in the proposed final pit surface were predicted to not be acid generating. Of the waste rock, approximately 9% was predicted to be potentially acid generating. Heap leach ore was apparently not tested, but sulfide ore had a NNP weighted average of -67 t/kt (acid generating). Juniper and Sage mill tailings were net acid neutralizing; Mule Canyon Mine ore, which is milled at Twin Creeks, was potentially acid generating. Tailings MWMP leachate concentrations exceeded drinking water standards for arsenic, antimony, cadmium, chromium, copper, iron, lead, mercury, silver, and selenium; tailings filtrate had elevated concentrations of zinc and chloride.

Infiltrating dewatering water was identified as having the potential to flush soluble salts, including chloride and nitrate, from the shallow alluvium to groundwater. The water also contained elevated concentrations of antimony, but observations prior to the DEIS indicate the alluvium could attenuate it. No significant impacts to groundwater quality were expected from the sulfide ore stockpiles or tailings due to low precipitation, groundwater depth and natural attenuation. The surface water in Rabbit Creek could be affected by the discharge of dewatering water, which has shown occasional exceedences of total dissolved solids (by 1-10 times) and arsenic (by >10 times). Testing showed that the pit lake could have water quality problems in both the short term and long term.

The DEIS proposed numerous mitigation; some were presented as design criteria and others were actual plans for monitoring and mitigation. Some waste rock would be placed over tailings, and thus seepage would be collected and discharged to process facilities, evaporated, or treated prior to discharge. Most waste rock dumps would be constructed on top of alluvium with net neutralizing potential and more than 100 feet to the groundwater after the dewatering drawdown recovers. A basal layer of acid neutralizing material would be placed underneath acid generating waste rock. Tailings facilities would be designed with liners, subdrains, collection ponds and pumpback systems to prevent migration of tailings waters into groundwater. Groundwater would be monitored to detect infiltration of mine water, with mitigation measures to follow if infiltration is detected. Heap leach pads would be designed with synthetic liner and leak detection system and operated as a zero-discharge facility; solution ponds were planned to be double-lined with leak detection systems. A bioremediation facility was proposed to treat hydrocarbon-contaminated soil.

For surface water discharge and discharge to the infiltration basin, treatment was proposed for dewatering water to remove arsenic. The connection between Jake Creek and the regional groundwater system will be evaluated, followed by monitoring for water quantity and quality. Diversion structures will be inspected to ensure proper function and combat soil loss. Drainage structures will be stabilized after completion of mining. The pit lake water quality will be monitored, but there was no plan identified to mitigate problems.

Mine dewatering would lower the regional groundwater elevation, but re-infiltration would increase water levels in the reinfiltration pond area by up to 70 feet, even though stream flow increase was not expected. Drawdown would potentially reduce baseflow in perennial streams and springs, including Little Humboldt River and Jake Creek. Pit water was not expected to discharge to groundwater, so no impacts to downgradient groundwater were expected.

Tailings facilities would be designed to be zero discharge to prevent migration of tailings waters into groundwater systems. Potential for adverse effects to water quality from sludge disposal was considered minimal. Limited or no impact was expected to occur from bioremediation facilities. Modeling showed that drinking water standards were predicted to be exceeded for antimony and arsenic (>10 times) and thallium (1 – 10 times) for the life of the pit. Aluminum concentrations were predicted to exceed standards in the north lobe of the pit for the first 27 years, but after the pit lakes merged, no exceedences were predicted. Steady state pit water quality would exceed TDS standards by 1-10 times. No net outflow from the pit to groundwater or surface water was expected.

Dewatering water discharged to Rabbit Creek has shown occasional exceedences of total dissolved solids and arsenic. However, the receiving water, Rabbit Creek, is dry and the flow will rarely reach Jake Creek, so downstream surface water quality impacts were predicted to be minimal. Discharge to infiltration basins was also expected to leach some salts into the underlying groundwater from the alluvium.

6.3.24.2. ACTUAL WATER QUALITY CONDITIONS

Water quality monitoring and compliance data were collected from the Nevada Department of Environmental Protection (NDEP) for the period 2000-2003. Seven groundwater monitoring locations were noted for the site. The following information on water quality was noted:

- Monitoring reports submitted show high arsenic concentrations in many wells. These reports refer to arsenic levels as background. However, the concentrations fluctuated by as much as two-fold, and the wells are screened in shallow alluvium. Some wells are located near the tailings impoundments. Therefore, the claim that arsenic concentrations are baseline requires further analysis.
- Cyanide was detected in monitoring well MW-2 in October 1995, from seepage in the Pinon tailings impoundment. Seepage is believed to have occurred when the supernatant pool was filled too deeply, which may have resulted in seepage through the tailings embankment in excess of the collection pipe’s capacity. Due to ongoing exceedences, there may be an ongoing leak. NDEP evaluated and characterized seepage fluids in the vadose zone below the facility and plugged well MW-2 because they believed it was acting as a conduit. The well was replaced with monitoring well MW-2R-1. Vadose zone wells (VW wells) were added to monitor seepage from the tailings impoundment. Vadose zone monitoring wells were added during 2003 to monitor seepage from the tailings impoundment (VW-1 through VW-26), and water quality in these wells is of poorer quality with multiple exceedences of TDS, sulfate, chloride, cyanide, aluminum, antimony, arsenic, manganese, iron and mercury. With possible exception of arsenic, it does not appear that tailings water regularly reaches the pre-existing alluvial groundwater.

6.3.24.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.29 provides a summary and comparison of potential, predicted and actual water quality information for the Twin Creeks Mine. The accuracy of the predictions is discussed in this section.

Table 6.29. Twin Creeks, NV, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impacts	Mitigation	Predicted Impacts	Actual Impacts
Groundwater	Tailings impound ment	Infiltrating dewatering water could flush soluble salts, including chloride and nitrate, from shallow alluvium to groundwater. Low potential for impacts from heap leach. No significant impacts from sulfide ore stockpiles or tailings.	Layer of acid-neutralizing material underneath overburden storage. Overburden placed over tailings, seepage collected and discharged to process facilities, evaporated, or treated prior to discharge. Tailings facilities have liners, subdrains, collection ponds, and pumpback systems. Heap leach pads have liner and leak detection, as well as double lined solution ponds with leak detection. Monitoring.	Dewatering would lower groundwater elevation, infiltration would increase levels in reinfiltration pond area up to 70 feet; stream flow increase not expected. Pit water not expected to discharge to GW, so no impacts. Tailings facilities have liners, subdrains, collection ponds, and pumpback systems.	The Pinon tailings impoundment formed a leak which caused a perched zone with poor water quality including high concentrations of WAD cyanide, arsenic, TDS and other constituents.
Surface Water	Dewater-ing water	Drawdown would potentially reduce baseflow in perennial streams and springs, including Little Humboldt River and Jake Creek.	Evaluation of connection between Jake Creek and groundwater system, followed by monitoring. Inspection of diversion structures to ensure function and combat soil loss. Stabilization of drainage structures after mining.	Potential for impacts from sludge disposal is considered minimal. Limited/no impact expected from bioremediation facilities.	Water discharged to Rabbit Creek has shown occasional exceedences (by 1-10 times) of total dissolved solids and arsenic (over 10 times).

<u>Leakage of Cyanide from Tailings Impoundment to Groundwater</u>: Geochemical testing showed that seepage from the tailings impoundment could degrade groundwater if the mitigation failed. The high concentrations of the vadose zone wells show that failure did occur. Therefore, the predictions that groundwater would not be degraded due to the zero discharge design were incorrect.

<u>Elevated Arsenic Concentrations in Groundwater</u>: There are questions about the baseline occurrence of arsenic in some of the wells. Because of their location and the variability of the concentrations, it cannot be determined whether the baseline condition, assumed by regulators, is correct. For this reason, it appears the characterization of the baseline water quality was insufficient.

6.3.25. FLAMBEAU, WISCONSIN

The Flambeau Mine, owned by Kennecott, was in operation from 1991 to 1995. The primary commodities mined were lead and zinc from open pit mining and flotation processing operations.

6.3.25.1. WATER QUALITY PREDICTIONS SUMMARY

NEPA was required for the new project to be permitted, and an EIS was completed in 1990. The following sections summarize the water quality predictions made in the NEPA document reviewed.

1990 EIS

Dominant rock types within the mineralized horizon are quartz-rich sediments and volcanic ash, massive sulfide, semi-massive sulfide, and chert. Economically valuable minerals are chalcocite, bornite and chalcopyrite, with trace amounts of gold and silver. The upper gossan cap is 30 feet thick. High-grade supergene copper (chalcocite, bornite in pyrite/chert) extends from below the gossan cap to a maximum depth of 225 feet. Lower grade copper sulfide minerals are present below the supergene-enriched zone.

Geochemical testing and modeling were conducted as part of the EIS. Wet/dry leach test (possibly humidity cell tests) and a second leach test of continued saturation of materials were conducted. Whole rock analysis and sulfur analysis were performed on waste rock (5 samples), topsoil, till, sandstone and saprolite samples. Acid production tests were performed on waste rock. Based on the results from leach tests and geochemical modeling, iron, manganese and sulfate were identified as constituents of concern. A geochemical model was used to predict the composition of leachate in the open pit backfill.

Acid drainage potential tests indicated that waste rock with a sulfur content of 2% or less would not be expected to produce acid. The matrix of the enriched horizon was made up of pyrite and chert. There was no indication of the amount of high sulfur material. Leach tests identified the potential for elevated concentrations of copper, iron, manganese and sulfate in interstitial waters in the backfilled pit. Waste rock from the mining operation would have the potential to leach contaminants to groundwater and surface water.

The EIS identified a number of proposed mitigation. High sulfur waste stockpiles and ore crushing/loading areas would be lined to prevent seepage. In the worst case scenario, leakage would leak into mine pit, where water would be treated before discharge. Settling ponds will collect runoff from low sulfur waste stockpiles for treatment prior to discharge to the Flambeau River. The ponds are proposed to be unlined, but seepage to groundwater would flow mostly to the open pit. Backfilling will eliminate the possibility of a pit lake, and the backfill will be limed. Water from the open pit, and the high sulfur waste rock pile would be routed through the wastewater treatment plant before being discharged to the Flambeau River.

The EIS identified a number of predicted impacts to groundwater, surface water and pit water. Slightly increased levels of TDS, hardness, sulfate, iron and manganese might be expected from leachate infiltration to groundwater. Contaminants would flow into the adjacent mine pit, where water would be treated prior to discharge to the Flambeau River. High sulfur waste stockpile, ore crushing and loading areas would be lined using a geomembrane; therefore, no impacts to groundwater quality were expected. Settling ponds would collect runoff from low sulfur waste stockpiles and seep into groundwater at a rate of at least 5,000-6,000 gallons/day; this could cause an increase in contaminant concentrations in the groundwater near the ponds. Most groundwater under the ponds would flow into the pit, limiting the potential zone of contamination. Surface water impacts could include increased soil erosion and discharge of sediment (increased turbidity) to the river. Discharge into the Flambeau River will not cause the concentration of any substances in the river to exceed the most stringent applicable water quality standards. The groundwater drawdown may affect additional acreage. A small amount of contaminants from the settling ponds may be transported in the groundwater to the Flambeau River but would not measurably affect the river water quality. After closure, discharge of contaminants would not likely be measurable in the Flambeau River due to dilution by the large river flow. Pit backfilling will eliminate pit waters. Modeled leachate concentrations in pit backfill were predicted to be 0.014 mg/l copper, 0.32 mg/l iron, 0.725 mg/l manganese, and 1,360 mg/l sulfate.

6.3.25.2. ACTUAL WATER QUALITY CONDITIONS

Monitoring and compliance data for the period 2000-2003 were obtained from the 2003 Annual Report, Groundwater and Surface Water Trends (Flambeau Mining Company, January 1, 2004). One surface water monitoring location and four groundwater monitoring locations were noted. The following water quality data was noted.

Four monitoring wells in the backfilled pit showed exceedences of drinking water MCLs or secondary standards for iron (up to 12 mg/l), manganese (up to 37 mg/l), pH (as low as 6.1), sulfate (up to 1,700 mg/l) and total dissolved solids (up to 3,400 mg/l). One in-pit well showed continued increasing or elevated concentrations of iron, sulfate, TDS and manganese; other wells showed decreasing concentrations. Groundwater elevations were higher in the backfilled pit than they were between the pit and the river, so water potentially flows from the pit to the river. After groundwater elevations returned to pre-mining levels, concentrations of iron, manganese, sulfate and TDS increased and pH decreased. Values for pH before pumping began were quite variable (5.8 - ~8.3). Concentrations appeared to peak in 2000 and were slowly decreasing for manganese (from a high of over 5,000 µg/l), sulfate (from a high of almost 700 mg/l) and TDS (from a high of ~1,300 mg/l), but are continuing to increase for iron (up to ~6 mg/l). Zinc concentrations were variable and still (as of 2003) ~700 µg/l (Lehrke, 2004).

Although concentrations in surface water up and downgradient of the mine showed no temporal water quality trends, a report from the Great Lakes Indian Fish and Wildlife Commission stated that water parameters measured have changed from those measured during mine operation, and that the change makes it impossible to compare during- and post-mining water quality (Coleman, 2004). In addition, the report states that the downstream sample site SW-2 is above the discharge point for surface water coming from the southeast portion of the mine site and therefore may not capture all releases from the mine.

6.3.25.3. COMPARISON OF PREDICTED AND ACTUAL WATER QUALITY

Table 6.31 provides a summary and comparison of potential, predicted and actual water quality information for the Flambeau Mine. The accuracy of the predictions is discussed in this section.

<u>Elevated Concentrations of Iron, Manganese, Sulfate, TDS and Acidity in Pit Backfill Leachate:</u> The concentrations of copper, iron, manganese and sulfate in the backfilled pit were predicted using geochemical modeling in the 1900 EIS. The modeling apparently used concentrations from short-term leach tests, but the details of modeling were not provided in the EIS. Predictions were also made in 1996 and 1997 as part of the mine's backfill plan. Concentrations predicted in 1997 for copper, manganese, and iron were substantially higher than those predicted in the EIS. For example, copper concentrations predicted in 1997 were 0.18 to 0.56 mg/l, and concentrations in the EIS were 0.014 mg/l. Compared to EIS-predicted post-mining concentrations in the pit backfill, post-mining concentrations in the backfill were higher by up to 45 times for copper, 70 times for manganese, 30 times for iron, and 1.25 times for sulfate. Therefore, modeling underestimated actual concentrations of metals and other contaminants in the pit backfill leachate.

Table 6.31. Flambeau, WI, Potential, Predicted and Actual Impacts

Resource	Source	Potential Impact	Mitigation	Predicted Impact	Actual Impact
Pit Backfill Leachate	Pit backfill	Pit backfill will eliminate pit waters.	Backfilling to eliminate possibility of a pit lake. Liming of backfill.	Pit backfill will eliminate pit waters. Predicted leachate concentration in pit backfill was 0.014 mg/l copper, 0.32 mg/l iron, 0.725 mg/l manganese and 1,360 mg/l sulfate.	Four monitoring wells in the backfilled pit show exceedences of drinking water standards for iron, manganese, pH, sulfate and TDS. One in-pit well shows continued increasing or elevated concentrations of iron, sulfate, TDS and manganese; other wells show decreasing concentrations.
Groundwater	Pit backfill	Waste rock from the mining operation would have the potential to leach contaminants to ground water.	High sulfur waste stockpiles and ore crushing/ loading areas lined. Treatment of mine water before discharge; Liming of backfill. Settling ponds to collect runoff from low sulfur stockpiles.	Slightly increased TDS, hardness, sulfate, iron and manganese may be expected from leachate infiltration. No impacts from high sulfur stockpile, ore crushing areas. Worst-case leakage would leak into mine pit, where water would be treated before discharge. Groundwater under ponds flows to pit, limiting contamination.	Samples taken from a well between the river and the pit show exceedences of drinking water standards for iron (2.8-7.4 mg/l), manganese (3.1-4.2 mg/l), pH (5.9-6.2), sulfate (250-460 mg/l), and TDS (810-1,100 mg/l).
Surface Water and Springs	Pit backfill and mine operations	Waste rock from the mining operation would have the potential to leach contaminants to surface waters.	Settling ponds collect runoff from low sulfur stockpiles for treatment prior to discharge. Ponds unlined, but seepage to groundwater would flow mostly to pit. Contaminant flow to pit treated prior to discharge to river.	Increased erosion and discharge to river possible. Discharge will not cause concentration of any substance to exceed standards. Contaminants from ponds may be transported to river, wouldn't affect water quality. Post-closure discharge of contaminants not measurable in river due to dilution.	No observable changes in surface water quality, but sample locations may not capture all releases from mine.

7. SUMMARY OF CASE STUDY FINDINGS AND INHERENT FACTORS AFFECTING OPERATIONAL WATER QUALITY

Section 7 presents a general summary of predicted and actual water quality for the 25 case study mines. To determine the accuracy of water quality predictions, statements made in the NEPA documents about potential and predicted water quality impacts were compared with actual operational water quality data, using information from Section 6. Water quality impacts from acid drainage and other contaminants may be delayed, depending on the amount and availability of neutralizing and acid-generating material, the distance to water resources, and other factors (Maest et al., 2005). Because mines that have not had water quality impacts to date may have impacts in the future, a greater emphasis is placed in this report on comparing predictions for mines that have already had water quality impacts.

"Inherent" factors affecting operational water quality at the case study mines are also identified and discussed. The potential inherent factors identified in the EISs that can affect water quality at mine sites include geology and mineralization, acid drainage and contaminant leaching potential, climate and proximity to water resources. If a strong relationship exists between certain of these factors and operational water quality for the case study mines, it may be possible to estimate in advance – knowing only what can be gathered from EISs – which mines may have better and worse environmental performance.

Section 7.1 presents the general findings on the accuracy of water quality predictions in the EISs and EAs. Section 7.2 presents information on the relationship between inherent characteristics (or combinations of characteristics) and actual water quality at the case study mines. Although predictions from all EISs for a given mine were considered, the initial predictions (i.e., in the first EIS or EA) are often the most important, because, with the exception of separate expansions, the major mitigating measures are based on these initial predictions. Although sample sizes are not large enough for statically valid comparisons, general statistical measures (simple percentages for a population with a given characteristic) are presented to indicate the importance of the associations discussed.

7.1. ACCURACY OF WATER QUALITY PREDICTIONS: SUMMARY OF CASE STUDY FINDINGS

Findings for individual case study mines are presented in Section 6. In Section 7.1, predicted and actual water quality data are reviewed for all 25 case study mines to determine if there are patterns in the accuracy of EIS water quality predictions.

7.1.1. ACID DRAINAGE/CONTAMINANT LEACHING POTENTIAL AND DEVELOPMENT

The potential for acid drainage is usually determined using static acid-base accounting tests, while the potential for contaminant leaching is usually determined using the results from short-term leach tests and analysis of the leachate for metal concentrations. Kinetic test results can be used to determine both acid drainage and contaminant leaching potential. It is possible to have neutral or even basic drainage and elevated contaminant concentrations, especially for constituents such as arsenic and other oxyanions, cyanide, and anions such as nitrate and sulfate. Therefore, these two geochemical characteristics (acid drainage and contaminant leaching) are discussed separately.

The results for acid drainage and contaminant leaching potential and development are contained in Tables 7.1, 7.2 and 7.3. The majority of the case study mines (18/25 or 72%) predicted low potential for acid drainage in one or more EIS. Of the 25 case study mines, 36% have developed acid drainage on site to date. Of these nine mines, eight (89%) predicted low acid drainage potential initially or had no information on acid drainage potential. The Greens Creek Mine in Alaska initially predicted moderate acid drainage potential but later predicted low potential for acid drainage for an additional waste rock disposal facility. Therefore, nearly all the mines that developed acid drainage either underestimated or ignored the potential for acid drainage in their EISs.

Table 7.1. EIS and Operational Water Quality Information for Case Study Mines

Site	State	Highest (Lowest) Acid Drainage Potential	Acid Drainage Developed on Site?	Contaminant Leaching Potential	Standards Exceeded in SW?	Constituent Increasing or Exceeding in SW	Standards Exceeded in GW?	Constituents Increasing or Exceeding in GW or Seeps
Greens Creek	AK	Moderate (Low)	Yes	Low	Yes	low pH, Cd, Cu, Hg, Zn, SO_4	No	GW: SO_4; seeps: SO_4, Zn, pH, Cu, Pb, Se
Bagdad	AZ	Low	Yes	No info	Yes	As, Pb, Hg, Se	No info	NA
Ray	AZ	No info	Yes	No info	Yes	TDS, NH_3, As, Be, Cu, turbidity	No info	NA
American Girl	CA	Low (0 initial)	No	Low (No info initial)	No	None	No	None
Castle Mountain	CA	Low	No	Low	No	None	No	None
Jamestown	CA	Low	No	Low	No info	NA	Yes	SO_4, NO_3, As
McLaughlin	CA	Low	Yes	Moderate	Yes	SO_4, As, Cr, Cu, Pb, Mn, Ni, Hg, Fe, Zn	Yes	TDS, Cl, NO_3, SO_4, Cu, Fe, Mn, B, Zn
Mesquite	CA	Low	No	Low (No info initial)	No	None	No	None
Royal Mountain King	CA	Low	No	No info	Yes	NO_3, SO_4, TDS, As	Yes	Cl, NO_3, Ni, Se, SO_4, TDS, Mn, As, Sb, Cr, Cu, Ni, CN
Grouse Creek	ID	Moderate	No	Low	Yes	CN	Yes	GW: CN; Tail pore water: Al, Cu, As, Se, Ag, Zn, CN
Thompson Creek	ID	Moderate (Low initial)	Yes	Low	Yes	Cd, Cu, Pb, Zn, SO_4	No info	Seeps: Fe, Zn, SO_4, Se; GW: NA
Beal Mountain	MT	Moderate (Low initial)	No	Low	Yes	NO_3, TDS, SO_4, CN	Yes	GW: NO_3, Fe, CN; TDS. Seeps: CN, Se, SO_4, NO_3
Black Pine	MT	High (no info initial)	Yes	Moderate	Yes	SO_4, Cu, Zn, Fe, Cd, low pH	No info	Seeps: low pH, SO_4, Cu, Zn, Fe, Cd; GW: NA

Table 7.1. EIS and Operational Water Quality Information for Case Study Mines (continued)

Site	State	Highest (Lowest) Acid Drainage Potential	Acid Drainage Developed on Site?	Contaminant Leaching Potential	Standards Exceeded in SW?	Constituent Increasing or Exceeding in SW	Standards Exceeded in GW?	Constituents Increasing or Exceeding in GW or Seeps
Golden Sunlight	MT	High (Low initial)	Yes	High	No	NA	Yes	CN, Cu, low pH
Mineral Hill	MT	Low	No	Moderate	Yes	CN, NO_3, Mn, SO_4, As, TDS	Yes	CN, NO_3, Mn, SO_4, As, TDS
Stillwater	MT	Low	No	Moderate	No	NO_3	No	Adit: Cd, Cu, Pb, Mn, Zn, NO_3. GW: Cr, Fe, SO_4, Cl, PO_4, Cd, Zn
Zortman and Landusky	MT	High (Low initial)	Yes	Moderate	Yes	metals, metalloids, NO_3, low pH, CN	Yes	low pH, As, metals, NO_3, CN
Florida Canyon	NV	Low	No	Moderate	No	NA	Yes	CN, Hg, NO_3, Cl, TDS
Jerritt Canyon	NV	Moderate	No	Moderate	Yes	TDS, SO_4	Yes	CN, Cl, TDS, SO_4
Lone Tree	NV	Moderate	No	High	Yes	pH, TDS, F, B, NH_3	Yes (baseline?)	F, Fe, Mn, TDS, Al, B, NH_4, pH
Rochester	NV	Moderate (Low initial)	No	Moderate	Yes	NO_3, As	Yes	CN, Hg, Cd, NO_3, As
Round Mountain	NV	Low	No	High	No info	NA	Yes (baseline?)	Al F, Fe, Mn, TDS, Sb, Pb
Ruby Hill	NV	Low	No	Moderate	No info	NA	Yes (baseline?)	As, NO_3, Pb
Twin Creeks	NV	Moderate	No	High	Yes	TDS, As	Yes - perched GW	TDS, SO_4, Cl, CN, Al, Sb, As, Mg, Fe, Hg, Mn
Flambeau	WI	No info	Yes	Moderate	No	SO_4, Mn, low pH, Fe	Yes	Fe, Mn, pH, SO_4, TDS

No info = no information; NA = not applicable; Ag = silver; Al = aluminum; As = arsenic; B = boron; Be = beryllium; Cd = cadmium; Cl = chloride; CN = cyanide; Cr = chromium; Cu = copper; F = fluoride; Fe = iron; Hg = mercury; Mn = manganese; Ni = nickel; NO_3 = nitrate; NH_4 = ammonia; Pb = lead; Sb = antimony; Se = selenium; SO_4 = sulfate; TDS = total dissolved solids; Zn = zinc.

Table 7.2. Acid Drainage Potential Predictions and Results for Case Study Mines (Percentages)

Element	Number/Total	Percentage
Mines predicting low acid drainage potential	18/25	72%
Mines that have developed acid drainage	9/25	36%
Mines with acid drainage that predicted low acid drainage potential	8/9	89%

Table 7.3. Contaminant Leaching Potential Predictions and Results for Case Study Mines (Percentages)

Element	Number/Total	Percentage
Mines predicting low contaminant leaching potential	8/25	32%
Mines with mining-related exceedences in surface water or groundwater	19/25	76%
Mines with exceedences that predicted low contaminant leaching potential	8/19	42%
Mines with exceedences that predicted moderate contaminant leaching potential	8/19	42%
Mines with exceedences that predicted high contaminant leaching potential	3/19	16%

Eight case study mines predicted low contaminant leaching potential (Table 7.3). Of these eight mines, five (63%) had exceedences of standards in either surface water or groundwater or both after mining began. The three mines that predicted low contaminant leaching potential and had no exceedences of water quality standards were the three California desert mines: American Girl, Castle Mountain and Mesquite. Stated another way, 21 of the 25 case study mines (84%) had exceedences of water quality standards in either surface water or groundwater or both (Table 7.1). The exceedences at two of these mines may be related to baseline conditions. Of the remaining 19 mines, eight (42%) predicted low contaminant leaching potential (or had no information), eight (42%) predicted moderate contaminant leaching potential, and only three (16%) predicted high contaminant leaching potential. Therefore, nearly half of the mines that had exceedences of water quality standards underestimated or ignored the potential for contaminant leaching potential in EISs. The constituents that most often exceeded standards or that had increasing concentrations in groundwater or surface water included toxic heavy metals such as copper, cadmium, lead, mercury, nickel, or zinc (at 12/19 or 63% of case study mines), arsenic and sulfate (11/19, or 58% each), and cyanide (10/19, or 53%).

7.1.2. PREDICTED AND ACTUAL IMPACTS TO SURFACE WATER RESOURCES

Table 7.4 lists the case study mines, their potential and predicted surface water quality impacts from the EISs, and whether or not there were mining-related impacts or exceedences in surface water. The results in percentages are presented in Table 7.5. Sixty percent (15/25) of the case study mines had mining-related exceedences in surface water. One mine, (Stillwater Mine, MT) had mining-related increases of nitrate in surface water, but concentrations have not exceeded standards.

Table 7.4. Predicted and Actual Impacts and Proximity to Surface Water Resources at Case Study Mines

Site	State	Highest (Lowest) Potential Impact to SW	Highest Predicted Impact to SW	SW Impact?	Standards Exceeded in SW?	Perennial Streams or Discharge?
Greens Creek	AK	Low	Low	Yes	Yes	Both
Bagdad	AZ	Low	Low	Yes	Yes	Discharge
Ray	AZ	No info	No info	Yes	Yes	Discharge
American Girl	CA	Moderate (Low initial)	Low	No	No	No
Castle Mountain	CA	Low	Low	No	No	No
Jamestown	CA	Moderate	Low	No info	No info	Perennial
McLaughlin	CA	Moderate	Moderate	Yes	Yes	Discharge
Mesquite	CA	Moderate (Low)	Low	No	No	No
Royal Mountain King	CA	No info	No info	Yes	Yes	No info (Perennial); No discharge
Grouse Creek	ID	Moderate (Low initial)	Low (no info initial)	Yes	Yes	Perennial
Thompson Creek	ID	Moderate	Moderate (Low)	Yes	Yes	Both
Beal Mountain	MT	Moderate (no info initial)	Low	Yes	Yes	Both
Black Pine	MT	No info	Low	Yes	Yes	Perennial
Golden Sunlight	MT	Low	Low	No	No	No
Mineral Hill	MT	Low	Low	Yes	Yes	Both
Stillwater	MT	Low (no info initial)	Low	Yes	No	Discharge (unused)
Zortman and Landusky	MT	High (no info initial)	High (Low initial)	Yes	Yes	Both
Florida Canyon	NV	No info	Low	No	No	No
Jerritt Canyon	NV	Moderate	Low	Yes	Yes	Perennial
Lone Tree	NV	Moderate	Low	Yes	Yes	Discharge
Rochester	NV	Moderate	Low	Yes	Yes	No
Round Mountain	NV	Moderate	Low	No info	No info	No
Ruby Hill	NV	Low	Low	No info	No info	No
Twin Creeks	NV	High	Low	Yes	Yes	Both
Flambeau	WI	Moderate	Low	No	No	Discharge

Table 7.5. Predicted and Actual Impacts to Surface Water Resources at Case Study Mines (Percentages)

Element	Number/Total	Percentage
Mines with mining-related surface water exceedences	15/25	60
Mines with surface water exceedences predicting low impacts without mitigation	4/15	27%
Mines with surface water exceedences predicting low impacts with mitigation	11/15	73%

A little over one-third (nine or 36%) of the case study mines noted a low potential for surface water impacts. Ten (40%) of the case study mines noted a moderate potential, and one noted a high potential for surface water quality impacts in the absence of mitigating measures. Of the 15 mines with exceedences of standards in surface water, three (20%) noted a low potential (pre-mitigation), seven (47%) stated that there would be a moderate potential, two stated there would be a high potential, and three had no information in their EISs on surface water quality impact potential in the absence of mitigation (Table 7.4).

In terms of predicted (post-mitigation) surface water quality impacts, 73% (11/15) of the mines with surface water quality impacts predicted low water quality impacts in their initial EISs, two predicted moderate impacts, and two had no information on post-mitigation impacts to surface water resources (Table 7.5). Therefore, the predictions made about surface water quality impacts before the effects of mitigation were considered were more accurate than those made taking the effects of mitigation into account. Stated in another way, the ameliorating effect of mitigation on surface water quality was overestimated in the majority of the case study mines. No mine conducted field or laboratory studies to determine the effects of mitigation on water quality improvement; rather, the predictions for both surface water and groundwater quality appeared to be based on unstated assumptions or best professional judgment.

Of the mines with surface water quality exceedences, only one mine(McLaughlin, CA) was correct in predicting a moderate potential for surface water quality impacts with mitigation in place; the others predicted low potential (not exceeding standards) in at least one EIS. However, the McLaughlin Mine predicted low acid drainage potential, and acid drainage has developed on site. Of the mines without surface water quality exceedences (seven or 28%), all were correct thus far in predicting no impacts to surface water with mitigation in place. Three of the seven are desert mines in California, one (Stillwater, MT) has had increases in contaminant concentrations but no exceedences, and the other three have had no exceedences or increases in mining-related contaminant concentrations in surface water to date. Therefore, most case study mines predicted no impacts to surface water quality after mitigation are in place, but at the majority of these mines, impacts have already occurred.

7.1.3. PREDICTED AND ACTUAL IMPACTS TO GROUNDWATER RESOURCES

Table 7.6 lists the case study mines, their potential and predicted groundwater quality impacts from the EISs ,and whether or not there were mining-related impacts or exceedences in groundwater or seeps. The results in percentages are presented in Table 7.7. The majority (64%,or 16/25) of the case study mines had exceedences of water quality standards in groundwater. However, exceedences at three of the mines, all in Nevada, may be related to baseline conditions; therefore, 52% of the case study mines clearly had mining-related exceedences of standards in surface water. Exceedences at one mine (Twin Creeks, NV) were said to be in “perched” groundwater. One mine (Greens Creek, AK) had mining-related increases of sulfate in groundwater, but concentrations have not exceeded standards. No information on groundwater quality impacts was available for four mines; however, two of these mines had mining-related exceedences in seeps. There were drinking water exceedences in adit water at the Stillwater Mine in Montana.

Table 7.6. Predicted and Actual Impacts and Proximity to Groundwater Resources at Case Study Mines

Site	State	Highest (Lowest) GW Impact Potential	Highest (Lowest) Predicted GW Impact	GW Impacts?	Standards Exceeded in GW?	Mining-related Exceedences in Seeps?	Shallow Groundwater or Discharge?
Greens Creek	AK	Moderate (Low)	Low	Yes	No	Yes	Shallow
Bagdad	AZ	Low	Low	NA	NA	NA	Shallow
Ray	AZ	No info	No info	NA	NA	NA	No
American Girl	CA	Moderate	Low	No	No	No	Shallow
Castle Mountain	CA	Low	Low	No	No	No	No
Jamestown	CA	Moderate	Low	Yes	Yes	NA	Shallow
McLaughlin	CA	High	High	Yes	Yes	NA	Shallow
Mesquite	CA	Moderate (Low initial)	Low	No	No	No	No
Royal Mountain King	CA	Moderate	No info	Yes	Yes	NA	No info
Grouse Creek	ID	Moderate (Low initial)	Low (no info initial)	Yes	Yes	NA	Shallow
Thompson Creek	ID	Moderate	Moderate (Low)	NA	NA	Yes	Shallow
Beal Mountain	MT	Moderate (no info initial)	Low	Yes	Yes	Yes	Shallow
Black Pine	MT	No info	Low	NA	NA	Yes	Shallow
Golden Sunlight	MT	High (Moderate)	High (Low initial)	Yes	Yes	Yes	Shallow
Mineral Hill	MT	Moderate	Low (no info initial)	Yes	Yes	NA	No
Stillwater	MT	Low (no info initial)	Low	No	No	Yes - adit	Both
Zortman and Landusky	MT	Moderate (Low)	High (Low)	Yes	Yes	Yes	Shallow
Florida Canyon	NV	Moderate	Low	Yes	Yes	NA	Shallow
Jerritt Canyon	NV	Moderate (Low initial)	Low (no info initial)	Yes	Yes	NA	Shallow
Lone Tree	NV	Low	Low	No? (baseline?)	Yes (baseline?)	NA	Shallow
Rochester	NV	Moderate (no info initial)	Low	Yes	Yes	NA	Shallow
Round Mountain	NV	High	Low	No? (baseline?)	Yes (baseline?)	NA	No
Ruby Hill	NV	Low	Low	No? (baseline?)	Yes (baseline?)	NA	No
Twin Creeks	NV	Moderate	Low	Yes	Yes - perched GW	NA	Discharge
Flambeau	WI	Moderate	Low	Yes	Yes	NA	Shallow

Table 7.7. Predicted and Actual Impacts to Groundwater Resources at Case Study Mines (Percentages)

Element	Number/Total	Percentage
Mines with mining-related groundwater exceedences	13/25	52%
Mines with groundwater exceedences predicting low impacts without mitigation	2/13	15%
Mines with groundwater exceedences predicting low impacts with mitigation	10/13	77%

About one-third of the case study mines (eight or 32%) noted a low potential for groundwater quality impacts in the absence of mitigating measures (Table 7.7). Of the 13 mines with mining-related exceedences in groundwater, only two noted a low potential for groundwater quality impacts in the original EIS, the majority (nine or 69%) stated that there would be a moderate potential, and two stated there was a high potential for groundwater impacts in the absence of mitigation (Table 7.7). In terms of predicted (post-mitigation) groundwater quality impacts, most of the case study mines (10 or 80%) predicted low groundwater quality impacts (not exceeding standards) after mitigation were in place. And an even higher percentage (10 or 77%) of the mines with exceedences in groundwater predicted low water quality impacts in their EISs (including mines predicting low impacts in the original EIS). Therefore, as with surface water, the predictions made about groundwater quality impacts without considering the effects of mitigation were somewhat more accurate than those made taking the effects of mitigation into account. Again, the ameliorating effect of mitigation on groundwater quality was overestimated in the majority of the case study mines.

Of the mines with mining-related groundwater quality exceedences (13), only one mine – the McLaughlin Mine in California – was correct in predicting a high potential for groundwater quality impacts with mitigation in place. This is the same mine that correctly predicted that there would be surface water exceedences. The others predicted low potential (not exceeding standards) for groundwater quality impacts in at least one EIS. Of the mines without groundwater quality exceedences (five or 25%), all were correct in predicting no impacts to surface water with mitigation in place. Again, three of the five are desert mines in California, one (Stillwater MT) has had increases in contaminant concentrations but no exceedences, and the other (Greens Creek, AK) has had mining-related exceedences in seeps. Therefore, most mines predicted no impacts to groundwater quality after mitigation were in place, but in the majority of case study mines, impacts have occurred.

7.2. INHERENT FACTORS AFFECTING WATER QUALITY AT CASE STUDY MINES

One of the goals of this study was to determine if there are certain factors that make a mine more or less likely to have water quality problems and more or less likely to accurately predict future water quality. Such factors could include: inherent characteristics of the mined materials; inherent characteristics of the mine; management approaches to handling mined materials and water; the type and number of geochemical tests that are performed on mined materials; and the interpretation of test results.

There are two types of water quality predictions in EISs: "potential" water quality (does not take mitigation into account) and "predicted" water quality (does take mitigation into account). As noted in Section 7.1, nearly all the EISs reviewed reported that they expected acceptable water quality (concentrations lower than relevant standards) after mitigation were taken into account. Indeed, if this prediction was not made in the EIS, the regulatory agency would not be able to approve the mine (with certain exceptions, such as pit water quality in states where pit water is not considered a water of the state).

Certain inherent characteristics of the mined materials or mining locations may make the mine more or less susceptible to water quality impacts and more or less likely to have accurate predictions about future water quality. Some of the inherent characteristics that may influence a mine's environmental behavior include:

- ore type and association (e.g., commodity, sulfide vs. oxide ore, vein vs. disseminated)
- climate (e.g., amount and timing of precipitation, evaporation, temperature)
- proximity to water resources (distance to surface water resources, depth to groundwater resources, presence of springs)
- pre-existing water quality (baseline groundwater and surface water quality conditions)
- constituents of concern
- acid generation and neutralization potentials (and timing of their release), and
- contaminant generation potential.

In addition to the inherent characteristics of a mine and its location, the management of the mine and its wastes and waters, the processing chemicals used, and the type of operation (e.g., vat leach and tailings vs. heap leach facility; underground vs. surface mine) will have an important effect on a mine's environmental behavior. The management and mitigation measures used can be one of the root causes of water quality problems, and these issues are addressed in Section 8.

This section examines the inherent factors that can influence environmental behavior at mine sites. Information from the EISs presented in Section 5, was used to evaluate the inherent factors and the mitigation measured used, and information on operational water quality at the case study mines, presented in Section 6 was used to determine if the identified water quality potential was accurate.

For this evaluation, a water quality impact is defined as increases in concentration of water quality parameters as a result of mining operations, whether or not an exceedence of water quality standards or permit levels has occurred. Information on whether groundwater, seep or surface water concentrations exceeded standards as a result of mining activity is also included.

Information gathered from the EISs was used to categorize the inherent characteristics of the mine and its materials. All of the potential inherent factors listed above were listed in the database under NEPA information. The inherent factors evaluated include: geology and mineralization; proximity to water resources and climatic conditions; and geochemical characteristics of mined materials, such as acid drainage and contaminant leaching potential.

Mines with close proximity to water resources and moderate to high acid drainage or contaminant leaching potential are examined together to determine if this combination of inherent factors results in a higher risk of adverse water quality impacts. Results for case study mines with this combination of factors are included in Tables 7.1, 7.4 (surface water) and 7.6 (groundwater and seeps). The tables list: the acid drainage and contaminant leaching potential: the presence of surface water or groundwater impacts: the presence of acid drainage on site; exceedence of standards in surface water, groundwater or seeps; constituents that have increased in concentration over baseline conditions or exceeded standards; the presence of perennial streams or shallow groundwater on site; and the type of discharge to surface water or groundwater. The discharges to surface water are usually permitted National Pollution Discharge Elimination System (NPDES) discharges under the Clean Water Act. The tables also include information from the EISs on water quality predictions, including the potential (pre-mitigation) and predicted (post-mitigation) impact to water resources.

7.2.1. MINES WITH CLOSE PROXIMITY TO SURFACE WATER AND MODERATE TO HIGH ACID DRAINAGE OR CONTAMINANT LEACHING POTENTIAL

EIS and operational water quality information for mines with close proximity to surface water and elevated acid drainage or contaminant leaching potential is listed in Tables 7.1 and 7.4.

Mines with Moderate to High Acid Drainage Potential

The following case study mines have perennial streams on site or discharge directly to surface water and have a moderate to high acid drainage potential (see Table 7.1):

- Greens Creek, Alaska
- Grouse Creek, Idaho
- Thompson Creek, Idaho
- Beal Mountain, Montana
- Black Pine, Montana
- Zortman and Landusky, Montana
- Jerritt Canyon, Nevada
- Lone Tree, Nevada
- Twin Creeks, Nevada

Of these nine mines, all (100%) had mining-related exceedences of water quality standards in surface water. Of the nine mines with identified moderate to high acid drainage potential and close proximity to surface water resources, four (44%) have currently developed acid drainage on site. Impacts to surface water from the other five mines resulted from cyanide, nitrate, sulfate, metalloids, ammonia or other anions (Table 7.1).

At the Greens Creek Mine, elevated concentrations of sulfate and zinc and lower pH values were measured in smaller streams, most likely as a result of leaching of high sulfide material (tailings or waste rock) lying outside of the tailings pile capture area. At the Grouse Creek Mine, tailings impoundment leakage into groundwater resulted in cyanide in surface water. At the Thompson Creek Mine, creeks downgradient of the waste rock dumps had increasing concentrations of sulfate (to values in excess of water quality standards) over a six-year period. At the Beal Mountain Mine, nitrate, total dissolved solids, and sulfate concentrations in streams have increased relative to baseline conditions, and cyanide exceeded aquatic life standards. At the Black Pine Mine, springs impacted by waste rock flow into Smart Creek and have elevated concentrations of sulfate, copper, zinc, iron, and cadmium, and low pH values. At the Zortman and Landusky Mine, streams were impacted by acid drainage from waste rock and the heap leach pad. The Lone Tree Mine has been in general compliance with overall permit requirements for discharge of its dewatering water to the Humboldt River, but there were some exceedences of permit limits, and Newmont has been fined for these exceedences. Although no information was obtained on stream water quality at the Twin Creeks Mine, dewatering water discharged to Rabbit Creek has shown exceedences of total dissolved solids and arsenic standards by up to 10 times.

Each of these nine mines predicted low surface water impacts after mitigation were in place in at least one or all of the EISs (Table 7.4). For the Thompson Creek and Zortman and Landusky mines, later EISs predicted higher potential impact to surface water, but in both cases, the initial EIS predicted low impacts to surface water resources. In a number of cases, the mines expanded before the development of poor water quality conditions. These results suggest that even though mines may identify a moderate to high acid drainage potential, they predict that surface water resources will not be impacted after mitigation are implemented. In all cases where elevated acid drainage potential was identified, the predicted impact to surface water was identified as “low” in at least one EIS, yet impacts have occurred (see Tables 7.1 and 7.4).

Mines with Moderate to High Contaminant Leaching Potential

The following mines have perennial streams on site or discharge directly to surface water and identified a moderate to high potential for contaminant leaching in their EISs (see Table 7.1):

- McLaughlin, California
- Black Pine, Montana
- Mineral Hill, Montana
- Stillwater, Montana

- Zortman and Landusky, Montana
- Jerritt Canyon, Nevada
- Lone Tree, Nevada
- Twin Creeks, Nevada
- Flambeau, Wisconsin

Of these nine mines, five also have moderate to high acid drainage potential and proximity to surface water resources and were discussed above. With the exception of the Flambeau Mine, which has developed acid drainage on site, all nine mines have had some impact to surface water quality from mining operations, as shown in Table 7.1. For nine mines with proximity to surface water resources and moderate to high contaminant leaching potential, eight (89%) have shown some impact to surface water quality, and seven (78%) of the nine mines have had exceedences of standards in surface water.

Of the remaining four mines, the McLaughlin Mine has had exceedences of sulfate (showing steady increases since mining began, and occasionally large exceedences of arsenic, chromium, copper, lead, manganese, mercury, iron and zinc. However, no surface water quality violations were recorded for the McLaughlin Mine because of the way baseline water quality is calculated. At the Mineral Hill Mine, tailings leachate containing cyanide, nitrate, manganese, sulfate, arsenic, and dissolved solids has escaped the liner system and caused exceedences in surface water. The Stillwater Mine does not have perennial streams on site, but it does have a NPDES permit for discharge of mine water to surface water. However, this permit has never been used. Nitrate concentrations in the Stillwater River have increased to as high as 0.7 mg/l (site-specific limit is 1.0 mg/l) as a result of mining activity, but no standards or limits were exceeded. At the Flambeau Mine, there were no observable changes in surface water quality, but there is some concern that surface water sample locations may not capture all releases from mine. The Flambeau Mine has had groundwater impacts from the backfilled pit. More monitoring of additional locations over a longer time period is required to determine if observed poor groundwater quality will adversely affect downgradient surface water.

In terms of EIS predictions, six of the nine mines identified moderate to high potential for surface water impacts without mitigation, but eight of the nine predicted low impacts to surface water after mitigation were in place (as noted above, the Zortman and Landusky Mine initially predicted a low impact to surface water resources). To date, predictions for surface water impacts at the McLaughlin, Stillwater and Flambeau mines were accurate, but the remaining six mines underestimated the actual impact to surface water in their EISs.

Comparison to All Case Study Mines

Surface water impacts for the mines with close proximity to surface water and high acid drainage or contaminant leaching potential are compared to surface water impacts for all the case study mines in Table 7.8. Overall, for the 13 mines with close proximity to surface water and high acid drainage or contaminant leaching potential (see Table 7.1), 12 (92%) have had some impact to surface water as a result of mining activity (see Table 7.5). For all case study mines, only 64% had some surface water quality impact. Eleven of the 13 (85%) have had exceedences of standards or permit limits in surface water as a result of mining activity. These results, although not comprehensive, suggest that the combination of proximity to surface water resources (including direct discharges to surface water) and moderate to high potential for acid drainage does increase the risk of water quality impacts. Although this finding makes intuitive sense from a risk perspective, a comprehensive study of cause and effect has never been conducted.

Of the 11 with exceedences, 10 (91%) predicted that surface water standards would not be exceeded. Considering the two mines that accurately predicted no surface water exceedences (Stillwater and Flambeau) and the one that accurately predicted exceedences (McLaughlin), 77% of mines with close proximity to surface water or direct discharges to surface water and moderate to high acid drainage or contaminant leaching potential underestimated actual impacts to surface water. For all case study mines, 73% of the mines with surface water quality exceedences predicted that there would be no exceedences. Compared to all case study mines, higher percentages of mines with close proximity to surface water and elevated acid drainage or contaminant leaching potential had surface water quality impacts and exceedences. EIS water quality predictions made before the ameliorating effects of mitigation were considered ("potential" water quality impacts) were more accurate at predicting operational water quality than predictions based on assumed improvements from mitigation. Mines with these inherent factors are the most likely to require perpetual treatment to reduce or eliminate the long-term adverse impacts to surface water resources.

Table 7.8. Surface Water Quality Impacts for Mines with Close Proximity to Surface Water and Elevated Acid Drainage Potential Compared to Surface Water Impacts for All Case Study Mines

	# Mines	Percent (%) with Impact to Surface Water	Percent (%) with Exceedences of Standards in Surface Water	Percent (%) with Exceedences that Predicted no Exceedences
Mines with close proximity to surface water and elevated acid drainage and contaminant leaching potential	13	92 (12/13)	85 (11/13)	91 10/11)
All case study mines	25	64 (16/25)	60 (15/25)	73 (11/15)

7.2.2. MINES WITH SHALLOW DEPTH OR DISCHARGES TO GROUNDWATER AND WITH MODERATE TO HIGH ACID DRAINAGE OR CONTAMINANT LEACHING POTENTIAL

The operational water quality of mines with shallow groundwater or discharges to groundwater resources – and with moderate to high acid drainage or contaminant leaching potential – is evaluated in this section. Mines with close proximity to groundwater resources are often close to surface water as well. Therefore, a number of mines evaluated above will also appear in this section. Mines that discharge to groundwater usually do so through infiltration basins or some other kind of land application. Although this is not a direct discharge to groundwater, it does increase the likelihood that the discharge water and any associated contaminants will reach groundwater. EIS and operational water quality information for mines with close proximity to groundwater and elevated acid drainage or contaminant leaching potential is listed in Tables 7.1 and 7.6.

Mines with Moderate to High Acid Drainage Potential

The following mines have a relatively shallow depth to groundwater (0 to 50 feet), have springs on site, or discharge to groundwater – and have a moderate to high acid drainage potential (see Table 7.1):

- Greens Creek, Alaska
- Grouse Creek, Idaho
- Thompson Creek, Idaho
- Beal Mountain, Montana
- Black Pine, Montana
- Golden Sunlight, Montana
- Zortman and Landusky, Montana
- Jerritt Canyon, Nevada
- Lone Tree, Nevada
- Rochester, Nevada
- Twin Creeks, Nevada

Of these 11 mines, some groundwater quality information was obtained for all but two (Thompson Creek, ID; Black Pine, MT). However, there is information about seepage water quality from both of these facilities. Of the 11 mines with shallow depths to groundwater, springs on site or that discharge to groundwater and that have moderate to high acid drainage potential, 10 (91%) have had some impact to groundwater or seeps from mining operations (see Table 7.6). The one exception is the Lone Tree Mine, which has groundwater exceedences that may be related to baseline conditions.

The Greens Creek Mine in Alaska has a depth to groundwater that ranges from the ground surface up to 50 feet deep. Seepage/runoff from the waste rock piles has an average zinc concentration of 1.65 mg/l, and tailings seepage water (including underdrain water) has had pH values as low as 5.8, with elevated sulfate (up to 2,400 mg/l), zinc (up to 3.6 mg/l), copper, lead, and selenium concentrations. Anomalously high sulfate concentrations were observed in groundwater monitoring wells, but metal concentrations have not increased as of 2000.

The Grouse Creek Mine has springs and shallow groundwater (depths ranging from 0.5 ft in alluvial aquifers to 100 ft in upland areas). The tailings liner and French drains installed below the tailings impoundment were not successful in preventing contamination from tailings leachate, and cyanide has been detected in both surface water and groundwater monitoring stations. Some contamination of groundwater is still evident at the site.

No groundwater data were obtained for the Thompson Creek Mine, which has flowing artesian wells, alluvial groundwater that is connected to streams, and some groundwater in bedrock fractures. However, tailings seeps have shown increases in iron and zinc, and sulfate and selenium concentrations in waste rock seeps were increasing since 1991, with selenium concentrations in excess of water quality standards.

At the Beal Mountain Mine in Montana, there is limited information on groundwater depth, but there are springs on site, and groundwater depth below the pit is only 25 to 50 ft Groundwater in the land application area exceeded standards for nitrate, iron and cyanide and had elevated total dissolved solids concentrations. Springs below the land application area also show appreciable increases in cyanide and selenium. Concentrations of selenium, sulfate, nitrate and total dissolved solids were elevated in springs sampled at the toe of the waste rock dump.

At the Black Pine Mine in Montana, groundwater depths are approximately 45 feet in the impoundment area, and there are 30 springs in the project area. Although no direct information on groundwater quality was available, seeps downgradient of waste rock and the soils barren areas are acidic (pH 2.6-4.7) and have elevated concentrations of sulfate, copper, zinc, iron and cadmium.

The Golden Sunlight Mine has alluvial groundwater at 50 to 60 feet deep and numerous springs on site. Tailings effluent has contaminated downgradient wells with cyanide and copper (up to 65 mg/l copper). Acid drainage is being produced from the waste rock dumps, ore stockpiles, tailings and adits.

The Zortman and Landusky Mine in Montana has perched groundwater at 140 to 150 feet, an overall depth to groundwater of <200 feet, and springs and seeps on site. Karst features control groundwater flow in some areas. Acid drainage has been generated from waste rock dumps (as low as pH 3.9), the ore heap retaining dikes, pit walls and floors, and leach pads and pad foundations. Sulfate concentrations have increased in alluvial groundwater downgradient of the heap retaining dikes.

The Jerritt Canyon Mine has perched groundwater at eight to 70 feet deep, and 23 springs and eight seeps on site. The regional groundwater depth is approximately 700 feet. Groundwater has been impacted by seepage from the tailings impoundment, and a cyanide plume exists on site. Groundwater in the vicinity of the tailings area also has exceedences of chloride (up to 12,000 mg/l), TDS (up to 30,000 mg/l) and sulfate.

Groundwater at the Lone Tree Mine ranges from 10 to >200 feet deep. Pre-mining groundwater levels have scored the mine as being close to groundwater resources, but the large dewatering rate for this mine has lowered groundwater levels considerably. The Lone Tree Mine in Nevada has had exceedences of primary and secondary drinking water standards in groundwater, but it is not clear if the cause is baseline conditions or seepage from mine facilities.

Depth to groundwater at the Rochester Mine ranges from <1 to 20 feet in the alluvial aquifer and from the ground surface to approximately 400 feet in the bedrock aquifer. There are springs on site. Leaks from the heap leach pad and the barren solution pond have caused numerous exceedences of WAD cyanide, mercury, cadmium, nitrate and arsenic in groundwater.
The Twin Creeks Mine, which operates a large dewatering system, has a groundwater depth of over 100 feet over most of the mine site; the pit floor is approximately 400 feet below pre-mining groundwater levels. However, the mine discharges to groundwater through infiltration basins. Degradation of groundwater (perched water) with cyanide and other constituents has occurred as a result of seepage from the tailings impoundment. The vadose zone monitoring wells that were added during 2003 to monitor seepage from the tailings impoundment have shown multiple exceedences of total dissolved solids, sulfate, chloride, cyanide, aluminum, antimony, arsenic, iron, mercury and manganese.

Therefore, for the 11 case study mines with close proximity to groundwater resources or that discharge to groundwater and that have moderate to high acid drainage potential, eight (73%) have shown some adverse impact to groundwater quality from mining activity. Of the remaining three mines in this category, two have contaminated seeps flowing from tailings and/or waste rock storage areas (Thompson Creek, ID; Black Pine, MT), but no groundwater quality data were obtained, for a total of 10 mines (91%) with mining-related impacts to groundwater or seeps. One mine in this category (Lone Tree, NV) has had no groundwater impacts. However, the groundwater table at the Lone Tree Mine has been lowered considerably from dewatering operations, and it is unlikely that groundwater impacts would be evident at this time.

For the 11 case study mines with close proximity to groundwater and elevated acid drainage potential, seven (64%) had mining-related exceedences in groundwater. Of the remaining four mines, three had mining-related exceedences in seeps, and one (Lone Tree) has baseline exceedences. All 11 mines (100%) predicted low groundwater impacts in one or more EIS after mitigation were in place (Table 7.6), but three mines (Thompson Creek, ID; Golden Sunlight and Zortman and Landusky, MT) also predicted higher impacts in at least one EIS. Only four mines predicted low groundwater impacts without mitigation. Therefore, the predictions that considered the effects of mitigation on groundwater quality were overly optimistic, and the predictions without mitigation were more accurate.

Mines with Moderate to High Contaminant Leaching Potential

The following mines are have a relatively shallow depth to groundwater (0 to 50 feet), have springs on site, or discharge to groundwater – and have a moderate to high contaminant leaching potential (see Table 7.1):

- McLaughlin, California
- Black Pine, Montana
- Golden Sunlight, Montana
- Stillwater, Montana
- Zortman and Landusky, Montana
- Florida Canyon, Nevada
- Jerritt Canyon, Nevada
- Lone Tree, Nevada
- Rochester, Nevada
- Twin Creeks, Nevada
- Flambeau, Wisconsin

Of these 11 mines, all but four (McLaughlin, CA; Stillwater, MT; Florida Canyon, NV; Flambeau, WI) also have moderate to high acid drainage potential and were discussed above. As noted earlier, all of these seven mines have had some impact to groundwater or springs/seeps as a result of mining activity with the possible exception of the Lone Tree Mine in Nevada, which has exceedences in groundwater that may be related to baseline conditions. In addition, the originally shallow groundwater table at the Lone Tree Mine has been lowered considerably from dewatering operations, and it is unlikely that groundwater impacts would be evident at this time.

The McLaughlin Mine in California has been touted by the mining industry as an example of a mine with laudable environmental behavior and has received numerous environmental awards. When the state of Wisconsin passed a requirement for new mines in sulfide ore bodies to demonstrate that other mines with net acid generation potential have operated and been closed for at least 10 years without polluting groundwater or surface water (Wisconsin Act 171 {Statute §293.50}, passed in 1997), the McLaughlin Mine was one of the three examples used by Nicolet Minerals in their application for a permit for the Crandon Mine (Nicolet Minerals, 1998). The McLaughlin Mine has a regulatory exclusion for groundwater at the site, so no groundwater enforcement actions can be brought by Regional Water Quality Control Board (RWQCB). At the McLaughlin Mine, wells downgradient of the tailings impoundment had exceedences of TDS (up to 12,000 mg/l), chloride, nitrate (up to ~37 mg/l), and sulfate, and increases of copper (up to 280 µg/l) and other metals from 1984 – 1992 (mine began operation in 1985). Wells downgradient of waste rock dumps had increasing concentrations of sulfate (up to 5,000 mg/l), boron, TDS, calcium, iron, manganese and other constituents from 1985 to 1998 and zinc (up to 1.7 mg/l) after this timeframe.

The Stillwater Mine in Montana has also received environmental awards, and acid drainage has not developed on the site to date, likely due in part to the unique ultramafic host rock and associated mineralogy. Depth to groundwater at the mine is 40 to 90 feet, and there are three springs on site; the mine discharges adit water to percolation ponds and a land disposal area on the site. Groundwater at the Stillwater mine in the area of the East land application disposal area has exceeded drinking water standards for chromium, but the cause is tailings from an historic government-operated World War II- era mine. The adit water that percolates to groundwater is unimpacted, except for nitrogen contamination, but contains cadmium, copper, lead, manganese, zinc and nitrogen concentrations in excess of baseline surface water values. Groundwater downgradient of the land application facility has slight elevations of sulfate, chloride, phosphorous, cadmium, iron and zinc, but these appear to be a baseline issue.

The pre-mining regional groundwater table at the Florida Canyon Mine was quite deep (~400 feet), but alluvial groundwater exists at 0 to 250 feet deep. A contaminant plume with elevated concentrations or exceedences of WAD cyanide, mercury, nitrate, chloride, and TDS exists in groundwater downgradient from the leach pad. Other groundwater monitoring wells on the site show exceedences of drinking water standards for aluminum, arsenic, cadmium, chloride, iron, manganese, nickel and TDS.

Depth to groundwater at the Flambeau Mine is Wisconsin before mining began was generally <20 feet and flowed toward the Flambeau River. Samples taken from a well between the river and the backfilled open pit showed elevated levels (compared to baseline values) or exceedences of drinking water standards for iron, manganese, pH, sulfate, and total dissolved solids. Concentrations appeared to peak in 2000 and have been slowly decreasing for manganese, sulfate and TDS, but are continuing to increase for iron. Zinc concentrations are variable and still (as of 2003) ~700 µg/l (Lehrke, 2004).

Of the mines that have close proximity to groundwater, springs on site, or that discharge to groundwater – and have a moderate to high contaminant leaching potential – eight of 11 mines (73%) had groundwater quality impacts, and two of the remaining three had seeps that were adversely impacted from mining activity (91% have mining-related impacts to groundwater, seeps, springs, or adit water). The remaining mine (Lone Tree, NV) has had exceedences of primary and secondary drinking water standards in groundwater, but it is not clear whether the cause is baseline conditions or seepage from mine facilities. All of the 11 mines had exceedences of standards in groundwater (8), or seeps, springs, or adits (4).

Of the 11 mines in this category, all but one (McLaughlin, CA) predicted low groundwater quality impacts after mitigation were installed. The Stillwater Mine in Montana predicted low impacts to groundwater, and no exceedences of standard have thus far resulted from current operations or operators. The Lone Tree Mine in Nevada also predicted low groundwater impacts, and current information suggests that this is true (assuming the exceedences are a baseline issue). However, the lowered water table likely prevents the observation of impacts to groundwater. EIS water quality predictions made before the ameliorating effects of mitigation were considered ("potential" water quality impacts) were more accurate at predicting operational water quality than predictions based on assumed improvements from mitigation. Therefore, of the 11 mines in this category, eight (73%) underestimated actual impacts to groundwater resources from mining activity.

Comparison to All Case Study Mines

Groundwater impacts for the mines with close proximity to groundwater and high acid drainage or contaminant leaching potential are compared to groundwater quality impacts for all the case study mines in Table 7.9. Taken as a whole, there are 15 mines with close proximity to groundwater, springs on site, or discharges to groundwater – and with moderate to high acid drainage or contaminant leaching potential (see Table 7.1 and 7.6). Of these 15 mines, 11 have had mining-related impacts to groundwater, and three have had adverse impacts to seeps, springs, or adit water (with the one possible exception being the Lone Tree Mine in Nevada), for a total of 14 (93%) with impacts to groundwater, seeps, or adit water. For all case study mines, only 14 (56%) had mining-related impacts to groundwater and three had mining-related impacts to seeps, for a total of 17 (68%) with impacts to groundwater, seeps or adit water.

Table 7.9. Groundwater Quality Impacts for Mines with Close Proximity to Groundwater and Elevated Acid Drainage Potential Compared to Groundwater Impacts for All Case Study Mines

	# Mines	Percent (%) with Impact to Groundwater or Seeps	Percent (%) with Exceedences of Standards in Groundwater or Seeps	Percent (%) with Exceedences that Predicted no Exceedences
Mines with close proximity to groundwater and elevated acid drainage and contaminant leaching potential	15	93 (14/15)	93 (14/15)	86 (12/14)
All case study mines	25	68 (17/25)	68 (17/25)	52 (13/25)

For the 15 mines with close proximity to groundwater and elevated acid drainage or contaminant leaching potential, 10 had mining-related exceedences in groundwater and four had mining-related exceedences in seeps or adit water, for a total of 14 (93%) with impacts to groundwater, seeps, or adit water. For all case study mines, 13 had mining-related exceedences in groundwater, and four more had exceedences in seeps or adit water, for a total of 17 (68%) with exceedences in groundwater, seeps, or adit water. Of the mines with groundwater, seep or adit water exceedences, 12 (86%) of those with close proximity to groundwater and high acid drainage or contaminant leaching potential predicted that there would be no exceedences (including those that predicted low potential in their initial EIS). For all case study mines with exceedences, 13 (52%) predicted that there would be no exceedences, including those that predicted low potential in their initial EIS. These results, although not comprehensive, suggest that the combination of proximity to groundwater resources (including discharges to groundwater) and moderate to high acid drainage or contaminant leaching potential does increase the risk of water quality impacts and is a good indicator of future adverse groundwater quality impacts.

7.3. SUMMARY AND CONCLUSIONS

Overall Findings

Of the 25 case study mines, nine (36%) have developed acid drainage on site to date. Nearly all the mines (8/9) that developed acid drainage either underestimated or ignored the potential for acid drainage in their EISs. Of the 25 case study mines, 19 (76%) had mining-related exceedences in surface water or groundwater. However, nearly half of the mines with exceedences (8/19 or 42%) predicted low contaminant leaching potential in their EISs. The constituents that most often exceeded standards or that had increasing concentrations in groundwater or surface water included toxic heavy metals such as copper, cadmium, lead, mercury, nickel, or zinc (12/19 or 63%), arsenic and sulfate (11/19 or 58% each), and cyanide (10/19 or 53%).

Sixty percent of the case study mines (15/25) had mining-related exceedences in surface water. Of the mines with surface water quality exceedences, four (17%) noted a low potential, seven (47%) a moderate potential, two a high potential, and three had no information in their EISs for surface water quality impacts in the absence of mitigation measures. For the mines with surface water quality exceedences, only one mine, the McLaughlin Mine in California, was correct in predicting a moderate potential for surface water quality impacts with mitigation in place. However, this mine predicted low acid drainage potential, yet acid drainage has developed on site. The other mines with surface water exceedences predicted low potential (not exceeding standards) for impacts in at last one EIS. Therefore, most case study mines predicted no impacts to surface water quality after mitigation were in place, but at the majority of these mines, impacts have already occurred.

The majority (64% or 16/25) of the case study mines had exceedences of drinking water standards in groundwater. However, exceedences at three of the mines, all in Nevada, may be related to baseline conditions; therefore, 52% of the case study mines clearly had mining-related exceedences of standards in surface water. Of the 13 mines with mining-related exceedences in groundwater, only two noted a low potential for groundwater quality impacts in the original EIS, the majority (nine or 69%) stated that there would be a moderate potential, and two stated there was a high potential for groundwater impacts in the absence of mitigation. In terms of predicted (post-mitigation) groundwater quality impacts, 77% (10/13) of the mines with exceedences predicted low groundwater quality impacts in their EISs (including mines predicting low impacts in the original EIS). Therefore, as with surface water, the predictions made about groundwater quality impacts without considering the effects of mitigation were somewhat more accurate than those made taking the effects of mitigation into account. Again, the ameliorating effect of mitigation on groundwater quality was overestimated in the majority of the case study mines.

Findings on Relationship Between Inherent Factors and Water Quality

Overall, for the 13 mines with close proximity to surface water and high acid drainage or contaminant leaching potential, 12 (92%) have had some adverse impact to surface water as a result of mining activity. For all case study mines, only 64% had some surface water quality impact. Eleven of the 13 (85%) have had exceedences of standards or permit limits in surface water as a result of mining activity. Of the 15 mines with close proximity to groundwater and high acid drainage or contaminant leaching potential, all but one (93%) have had mining-related impacts to groundwater, seeps, springs, or adit water. For all case study mines, only 56% had mining-related impacts to groundwater.

For the 15 mines with close proximity to groundwater and elevated acid drainage or contaminant leaching potential, 13 (87%) had mining-related exceedences in groundwater. For all case study mines, only 52% had exceedences in groundwater. These results, although not comprehensive, suggest that the combination of proximity to water resources (including discharges) and moderate to high acid drainage or contaminant leaching potential does increase the risk of water quality impacts and is a good indicator of future adverse water quality impacts. Although this finding makes intuitive sense from a risk perspective, a comprehensive study of cause and effect has never been conducted. Mines with these inherent factors are the most likely to require perpetual treatment to reduce or eliminate the long-term adverse impacts to surface water resources.

8. FAILURE MODES AND ROOT CAUSES OF WATER QUALITY IMPACTS

This section identifies the underlying causes of water quality impacts at the case study mines. It uses information gathered from the case studies presented in Section 6 and conducts a "failure modes" and "root cause" analysis. A failure is an outcome that is different than intended or predicted. A failure mode is the general type of failure that occurred or is predicted to occur (e.g., prediction failure, mitigation failure), while a root cause is the underlying, more specific, reason for the failure. The objective of the analysis presented in this section is to identify the most common types and causes of failures in protecting water quality at existing mines so that the failures can be prevented in future. Results from this analysis can be used to make recommendations for improving both the policy and scientific/engineering underpinnings of EISs.

8.1. METHODOLOGY AND APPROACH

The approach presented in this section uses existing ("historical") information from mines with EISs to identify the causes of water quality impacts that occurred during mining operations. In contrast, most failure modes effects analyses (FMEA) are conducted before operations begin and instead focus on generating predictions from engineering design information (e.g.,, likelihood of failure based on factor of safety calculations). Because our approach is retrospective rather than prospective, we know unequivocally whether a prediction has failed or a water quality failure has occurred. Therefore, the focus of this analysis is to determine what caused the failure to occur. The information used to determine how failure occurred is contained in Section 6, which summarizes and compares water quality predictions in EISs with actual water quality conditions during mining operation.

8.1.1. FAILURE MODES AND ROOT CAUSES

According to Robertson (2003), any approach or mitigation measure that does not achieve the intended result (e.g., to prevent water quality impacts) or that results in undesirable consequences is considered a "failure." This study has identified two primary types, or modes, of failures: characterization and mitigation. Root cause refers to the specific reason or reasons for the failure. Table 8.1 summarizes the failure modes and root causes for all water quality or prediction failures that can be identified in the case studies.

There are two types of characterization failures identified in the case studies: hydrologic and geochemical. Inaccuracies in hydrologic and geochemical characterization can lead to failure to recognize or predict water quality impacts. The primary root causes of hydrologic characterization failures identified in this study are:

- dilution overestimated
- lack of hydrological characterization
- amount of discharge overestimated, and
- size of storms underestimated.

The primary root causes of geochemical characterization failures identified are:

- lack of adequate geochemical characterization, and
- sample size and/or representation.

The other failure mode identified in the case studies is mitigation failures. The primary root causes of mitigation failures identified are:

- mitigation not identified, inadequate or not installed
- waste rock mixing and segregation not effective
- liner leak, embankment failure or tailings spill, and
- land application discharge not effective.

Table 8.1. Water Quality Predictions Failure Modes, Root Causes and Examples from Case Study Mines

Failure Mode	Root Cause	Examples
Hydrologic Characterization	Lack of hydrologic characterization	Royal Mountain King, CA; Black Pine, MT
	Dilution overestimated	Greens Creek, AK; Jerritt Canyon, NV
	Amount of discharge underestimated	Mineral Hill, MT
	Size of storms underestimated	Zortman and Landusky, MT
Geochemical Characterization	Lack of adequate geochemical characterization	Jamestown, CA; Royal Mountain King, CA; Grouse Creek, ID; Black Pine, MT
	Sample size and/or representation	Greens Creek, AK; McLaughlin, CA; Thompson Creek, ID; Golden Sunlight, MT; Mineral Hill, MT; Zortman and Landusky, MT; Jerritt Canyon, NV
Mitigation	Mitigation not identified, inadequate, or not installed	Bagdad, AZ; Royal Mountain King, CA; Grouse Creek, ID
	Waste rock mixing and segregation not effective	Greens Creek, AK; McLaughlin, CA; Thompson Creek, ID; Jerritt Canyon, NV
	Liner leak, embankment failure or tailings spill	Jamestown, CA; Golden Sunlight, MT; Mineral Hill, MT; Stillwater, MT; Florida Canyon, NV; Jerritt Canyon, NV; Lone Tree, NV; Rochester, NV; Twin Creeks, NV
	Land application discharge not effective	Beal Mountain, MT

8.2. EXAMPLES OF CHARACTERIZATION FAILURES FROM CASE STUDY MINES

The following sections provide examples of the various types of characterization failures that were identified from the case study mines in Section 6. The information provided is intended as a short summary identifying the failure modes, root causes and subsequent mitigation. More specific information describing the cause and effects in each case is available in Section 6.

8.2.1. HYDROLOGIC CHARACTERIZATION FAILURES

Incorrect or inadequate hydrological characterization was identified as a contributing factor to water quality impacts at six of the 25 mines evaluated. The failure modes and root causes and effects for each case study with hydrologic characterization failures identified in Table 8.1 are summarized in the following sections.

<u>Greens Creek, Alaska</u>

The original Greens Creek 1983 EIS predicted that dilution would prevent impacts to surface water; however, the 2003 EIS shows that surface water impacts were noticeable in the general mine area and in off-site streams. Stream tributaries were impacted by mine wastes, in part ,due to smaller than predicted flows not providing sufficient dilution of contaminants coming from tailings and waste rock piles. The impacts to surface water were subsequently mitigated by relocating waste rock and capturing and treating tailings leachate.

Royal Mountain King, California

Current data for the Royal Mountain King site shows impacts to groundwater in the vicinity of the waste rock dumps due to near surface groundwater that is resulting in lateral flow and spread of contamination originating from waste rock dump seepage. A more adequate hydrological assessment would have indicated the presence of near surface groundwater and could have allowed for relocation of the waste rock dumps in locations that would not result in groundwater and surface water impacts.

Black Pine, Montana

The waste rock dump has impacted groundwater and springs on the site with acid drainage and is discharging to headwater streams. A lack of hydrologic characterization at the site has led to difficulties in identifying the association between the waste rock dump and springs and seeps at the site and in determining cost effective mitigation methods.

Mineral Hill, Montana

According to the original EIS, the initial low discharge rate (approximately 1gpm) from the underground workings would not result in an appreciable amount of leachate from the workings. At the higher discharge rates (approximately 10 gpm) that existed during operation the amount of discharges were significant and resulting arsenic concentrations exceeded non-degradation water quality standards. The hydrologic characterization conducted for the EIS did not predict significantly more groundwater being encountered by underground mining activities. A more accurate hydrologic evaluation could have allowed for planning of water treatment of mine discharge and may have encouraged a more accurate geochemical characterization.

Zortman and Landusky, Montana

Surface water impacts were associated with storm events exceeding the 100-year design criteria. During the past 25 years, at least four storm events have exceeded the predicted 100-year storm event. In addition to improper design criteria for the mine units and the lack of run-on ditches to prevent upgradient additions to storm events, this suggests that the extent of hydrologic characterization in terms of storm frequency and strength (i.e. amount of rainfall) prediction was inadequate to properly design mine units.

Jerritt Canyon, Nevada

The original 1980 EIS predicted that dilution would prevent impacts to surface water from contaminants. However, subsequent water monitoring data shows that surface water impacts have occurred in the headwaters of streams in the project area, most likely due to contamination from waste rock. Streams were impacted by waste rock in part due to smaller than predicted flows not providing sufficient dilution of contaminants. A more adequate hydrological assessment could have indicated that low flows in headwater streams would not provide adequate dilution.

8.2.2. GEOCHEMICAL CHARACTERIZATION FAILURES

Incorrect or inadequate geochemical characterization was identified as a contributing factor to water quality impacts at 11 of the 25 mines evaluated. The causes and effects for each case study with geochemical characterization failures are summarized below and in Table 8.2.

Greens Creek, Alaska

The Greens Creek 1988 EA predicted no potential for acid drainage in tailings. The 2003 EIS predicted that acid drainage from the tailings would occur but would not become evident for 10 to 33 years (based on static testing) or 500 years (based on modeling results). The 1983 EIS did not address water quality impacts from waste rock, whereas the 1992 EA recognized the potential for acid drainage from waste rock to impact water quality. However, acid drainage is already evident at the site in the general mine area in the form of metal-rich seepage from either the tailings, waste rock, or both sources, suggesting that the geochemical characterization for the predictions in the EISs were not accurate. The root cause of the failure to accurately predict acid drainage could be due to a single factor or a combination of factors such as sample representation, geochemical analysis, modeling and/or interpretation.

Jamestown, California

The geochemical characterization testing (short-term leach tests only) performed for the 1983 and 1991 EIS/EIR did not accurately identify the potential for groundwater impacts that were evident by 1990. Test results indicated that the mine tailings would not contain contaminants that needed to be controlled, and that the overburden material was non-hazardous, non-toxic and non-acid generating. Arsenic and TDS drinking water standards were slightly exceeded in tailings leachate from short-term leach tests, but observed concentrations in groundwater were substantially higher. Therefore, the short-term leach tests were not effective at identifying the contaminants of concern (sulfate and nitrate were not identified as contaminants of concern but exceeded drinking water standards in groundwater) and also underestimated the actual concentrations of constituents in groundwater during operations. In addition, no short-term leach testing was performed on waste rock. The most likely reasons the geochemical characterization failed to identify the potential is due to either sample representation or inadequate geochemical analysis (e.g., failure to perform tests or to perform the appropriate tests, e.g., long-term kinetics tests).

McLaughlin, California

Geochemical characterization conducted in the original McLaughlin Mine EIS appears to have been inadequate, possibly due to inadequate sample representation, lack of kinetic testing, or modeling of results. Acid-base accounting results for waste rock removed from the pit showed that 92% of the waste rock was determined to be either neutral or neutralizing. These results were not accurate for longer-term weathering of waste rock as demonstrated by water quality impacts to groundwater, surface water and pit water at the site. Acid drainage has developed and water resources were impacted by multiple constituents (metals, arsenic, and sulfate).

Royal Mountain King, California

The Royal Mountain King 1987 EIS/EIR did not predict contamination associated with waste rock, however groundwater results show evidence of contamination indicating that geochemical characterization was inadequate. No contaminant leaching potential testing was conducted, but groundwater is contaminated with metals, anions and cyanide. The most likely cause of the failure of geochemical characterization to predict the potential for contamination was static testing results not being accurate for long-term weathering of waste rock. The TTLC levels (standards) used in the static tests also may not have been protective enough to prevent groundwater contamination, or the samples selected for testing may not have been representative.

Grouse Creek, Idaho

The Grouse Creek 1984 EIS did not predict that contaminant leaching from tailings would impact water quality. Initial geochemical characterization tests were apparently conducted on non-representative samples or the “weathering’ tests performed were not adequate to infer contaminant potential. Although moderate acid drainage potential was identified in the 1992 EIS, only lead was predicted to exceed drinking water standards in tailings leachate. The 2002 EE/CA showed that prediction to be in error, with actual tailings pore water showing exceedences of standards for aluminum, copper, arsenic, selenium, silver, zinc and cyanide.

Thompson Creek, Idaho

Acid drainage potential tests were not performed on tailings material in the Thompson Creek 1980 EIS. Acid-base accounting tests conducted on waste rock for the 1980 EIS did not predict acid drainage potential, and the tailings were thought to be similar to waste rock in terms of acid drainage potential, although no support for this assumption was provided. The 1999 EIS geochemical characterization tests included kinetic testing and did indicate the potential for acid drainage from waste rock because the NP:AP ratio was 1.5 to 3.1. ABA and kinetic tests performed on tailings material for the 1999 EIS did note that tailings could become acid generating if exposed to air and water. However, the tailings were predicted to not generate acid as long as saturated, oxygen-free conditions were maintained in the impoundment. The characterization predictions failure for the tailings material was in part related to an incorrect assumption that such conditions would exist and be maintained in the impoundment and that they would prevent acid drainage from developing.

Black Pine, Montana

The original Black Pine 1981 EA did not directly test for acid drainage potential but instead used the total sulfide in the ore (<0.2%) as indicative of low potential for acid drainage generation and impacts. The waste rock dump has since impacted groundwater and springs on the site with acid drainage and is discharging to headwater streams.

Golden Sunlight, Montana

The Golden Sunlight 1981 EIS specifically identified the potential for impacts to groundwater, and ABA testing did identify the potential for the ore to be acid producing. However, these results were dismissed because the ore used in the tests was finely ground (400 mesh) rather than being run-of-mine size, and was therefore considered to not be representative of field conditions. The results were also dismissed because previous historic mining activity and waste dump development on the project area did not result in acid drainage, and because there was no discharge from existing underground workings at the site. The ABA test results were qualified based on a statement from the testing laboratory (B.C. Research) that "Experience has shown that generally relatively more gangue than sulphides is exposed at the larger particle size although this may not always be the case." According to the 1990 EA, the analysis was of a single "highwall composite," and the exact location and means of obtaining the sample were unknown. After the 1981 EIS, all subsequent EISs or EAs acknowledged the high potential for acid drainage development.

Mineral Hill, Montana

The potential for elevated arsenic concentrations in groundwater from the mine workings was not specifically recognized in the geochemical characterization of the site conducted in the 1983 EIS or 1988 EA. No geochemical characterization tests were conducted on waste rock, ore or any material representative of the walls of the underground workings. Geochemical characterization on the tailings material did predict the observed increases in three of six constituents found in tailings leachate, and contaminated groundwater and surface water (cyanide, arsenic, and manganese), but not sulfate, nitrate, and TDS, which are not removed by commonly used mine water treatment techniques (e.g., lime precipitation).

Zortman and Landusky, Montana

The Zortman and Landusky 1979 new project EISs were conducted without any geochemical characterization. Acid drainage was not predicted to occur based on the assumption that only oxide ore would be mined. This resulted in heap leach dikes and foundations being constructed in surface water drainages using what later was determined to be a mixed oxide/sulfide waste rock with high acid drainage generating potential, and waste rock with high acid drainage potential to be similarly placed in surface water drainages. The consequences of mine expansion were not addressed until the 1996 EIS. By this time, many unpredicted impacts had occurred, resulting in significant contamination of groundwater and surface water resources.

Jerritt Canyon, Nevada

The initial geochemical characterization in the 1980 EIS did not include acid drainage potential tests and noted only minimal potential for leaching of contaminants from waste rock. The 1994 EIS, based on significant additional testing, did indicate potential for acid drainage and contaminant leaching from at least some materials. The geochemical characterization in the 1980 EIS most likely failed to predict a high enough potential for contamination due to either sample representativeness or the limited geochemical analysis methods employed. Although acid drainage has not developed, the waste rock contamination has since caused off-site impacts to surface water in the mine area for sulfate and TDS.

8.3. MITIGATION FAILURES

Failure of mitigation to perform was identified as a contributing factor to water quality impacts at 16 of the 25 mines evaluated. The cause and effects for each case study are summarized below.

Greens Creek, Alaska

The 1992 EA recognized the potential for acid drainage from waste rock and proposed mixing of acid generating and non-acid generating rock as a mitigation measure. The 2003 EIS water quality information shows that mixing was not effective to prevent water quality impacts in the general mine area. The 2003 EIS proposed backfilling of all waste rock to prevent acid drainage impacts.

Bagdad, Arizona
The Bagdad 1996 EIS did not predict any potential for impacts. Monitoring showed that impacts to off-site surface water occurred in 1998-2002, likely due to past tailings or pregnant leach solution spills or more recent events. The mitigation intended by the impoundment of tailings and pregnant leach solution failed in the form of a tailings spill or leak resulting in continued off-site impacts to surface water in the mine area.

Jamestown, California
The Jamestown project employed a sub-compacted liner and poorly designed embankment identified in the original EIS as mitigation for the tailings facility. The liner and embankment failed to protect groundwater quality.

McLaughlin, California
The McLaughlin 1983 EIS/EIR predicted that mitigation measures (underdrains, diversion ditches, segregation of PAG rock, lime addition to waste rock runoff) would avoid impacts to groundwater. However, groundwater wells downgradient of waste rock show water quality impacts indicating that the measures, such as mixing and segregation were not effective, resulting in widespread on-site impacts to groundwater and surface water.

Royal Mountain King, California
The Royal Mountain King 1987 EIS/EIR recognized the potential for impacts from tailings but assumed that low permeability material below the tailings would be sufficient as mitigation to protect groundwater. Similarly, the EIS/EIR recognized the potential for impacts from heap leach material, but assumed that a liner (material not specified) would prevent impacts to groundwater. Groundwater contamination downgradient of the tailings impoundment and heap leach area demonstrates that the low permeability material and liner have not prevented groundwater contamination.

Grouse Creek, Idaho
The contingency for groundwater capture and treatment during operations if necessary was mentioned in the Grouse Creek 1992 SEIS, however it was not installed at that time. The existing mitigation employed in the tailings impoundment (French drain designed to allow for capture of tailings leakage) proved to be ineffective at mitigating groundwater and subsequent surface water impacts to off-site water resources that occurred beginning in 1995. Additional mitigation in the form of groundwater capture and treatment has since been employed and has resulted in no detected impacts to surface water since 2001.

Thompson Creek, Idaho
According to the EIS, any acid-producing rock would be mitigated by special handling (segregation) and isolation techniques that are "demonstrated by their use throughout the mining industry." The methods employed at the mine site did not result in mitigation of acid drainage producing rock and instead led to water quality impacts that have required additional mitigation.

Beal Mountain, Montana
The LAD of leach solution, proposed as mitigation in the Beal Mountain 1993 EIS, resulted in damage to vegetation and contamination of groundwater and surface water with cyanide. The LAD system has failed at Beal Mountain because pre-treatment did not adequately reduce contaminants of concern (in particular cyanide compounds, which proved to be toxic to vegetation) and because there was significant groundwater percolation of contaminated solution and relatively rapid (within the same year) transport to surface water.

Golden Sunlight, Montana
The mitigation for the tailings impoundments identified in the Golden Sunlight 1981 EIS and the later 1990 EA failed due to liner design and construction errors and did not prevent migration of leachate from tailings. Contaminated groundwater from the impoundments has sometimes escaped capture systems due to more extensive leakage than

anticipated and operational deficiencies (periodic failure to maintain and operate pumpback system). The design approach for the tailings impoundment with respect to cyanide solution leakage was projected to achieve "from the practical engineering standpoint," a zero discharge facility. The clay liner in the original tailings impoundment and the synthetic liner in the newer tailings impoundment both failed to meet expectations and have resulted in a discharging facility that requires extensive groundwater capture to prevent more extensive groundwater and surface water impacts.

Mineral Hill, Montana

According to the 2001 EIS, the tailings facility design resulted in unanticipated lateral flow that escaped the liner system, resulting in contamination of alluvial groundwater and surface water. The design error occurred due to a lack of consideration of leachate emanating from the tailings impoundment as well as failure to recognize the potential for lateral flow.

Stillwater, Montana

In 2003 it was determined that a tailings underdrain discharge pipe was improperly designed or constructed and was allowing a leak of approximately 10 gpm to groundwater in the vicinity of the dam toe. It was also determined that the LAD solution storage pond liner was not performing as specified ($1x10^{-6}$ cm/sec) and that as much as 150 gpm of solution was seeping into groundwater. In both cases groundwater standards of 2.0 mg/l nitrate were not exceeded in compliance wells, although nitrogen concentrations increased in downgradient wells. The tailings underdrain pipe was repaired and the seepage is no longer detectable. The compacted clay liner in the LAD solution pond was replaced with a synthetic geomembrane liner.

Florida Canyon, Nevada

The exceedences of water quality standards at the Florida Canyon mine from the leach pads is primarily due to failure of mitigation (design, construction and/or operational errors) to adequately prevent leakage of leach solutions.

Jerritt Canyon, Nevada

The mitigation described in the 1980 EIS for the tailings impoundment, a compacted clay liner and embankment constructed to control seepage, failed as shown by the presence of a significant contaminant plume in the groundwater downgradient of the tailings facility. The failure of the liner and embankment seepage control system appears to be due to higher than design permeability most likely indicating either a problem with construction materials or construction practices.

The 1994 EIS proposed mixing and segregation as mitigation for potential acid drainage and contaminant leaching from waste rock. Subsequent monitoring data shows that waste rock continued to contaminate surface water despite implementation of the mitigation.

Lone Tree, Nevada

The tailings impoundment experienced a significant leak that resulted in leachate escaping into the vadose zone. An operational error (tailings were not placed against the embankment) was identified as the cause of the seepage. Newmont commenced remediation activities, which included trenching, and modified operations to promote drying of tails in the area of the embankments.

Rochester, Nevada

The mine has experienced exceedences of groundwater standards in the vicinity of the heap leach pile and ponds due to either spills or leaks in the liner system. Groundwater pump and treat is being used as a mitigation measure and is discussed in the 2003 EA.

Twin Creeks, Nevada

Leachate from the tailings impoundment has degraded groundwater in the vadose zone. An ongoing monitoring program is in place to determine the extent of vadose zone and potential groundwater contamination.

8.4. SUMMARY OF RESULTS

The Failure modes and effects identified in the study are summarized in Table 8.2. The results can be summarized as follows:

Six of 25 mines exhibited inadequacies in hydrologic characterization.

- At two of the mines, dilution was overestimated.
- At two of the mines, a lack of hydrologic characterization was noted.
- At one of the mines, the amount of discharge generated was underestimated.
- At one of the mines, the size of storms was underestimated.

Eleven of 25 mines exhibited inadequacies in geochemical characterization. Geochemical failures resulted from:

- assumptions made about geochemical nature of ore deposits and surrounding areas (e.g., mining will only be done in oxidized area)
- site analogs inappropriately applied to new proposal (e.g., historic underground mine workings do not produce water or did not indicate acid generation)
- inadequate sampling (e.g., geochemical characterization did not indicate potential due to composite samples or samples not being representative of actual mining)
- failure to conduct and have results for long-term contaminant leaching and acid drainage testing procedures before mining begins, and
- failure to conduct the proper tests, or to improperly interpret test results, or to apply the proper models.

Sixteen of 25 mines exhibited failures in mitigation measures.

- At three of the mines, mitigation was not identified, inadequate, or not installed.
- At four of the mines, waste rock mixing and segregation was not effective.
- At nine of the mines, liner leaks, embankment failures or tailings spills resulted in impacts to water resources.
- At one mine, land application disposal resulted in impacts to water resources.

Table 8.2. Summary of Failure Modes for Case Study Mines

Failure Mode	Number of Case Study Mines Showing Failure Mode	Percent of Case Study Mines Showing Failure Mode
Hydrologic Characterization	6	24%
Geochemical Characterization	11	44%
Mitigation	16	64%

8.5. CONCLUSIONS AND RECOMMENDATIONS

This study shows a variety of failure modes and root causes that have led to water quality impacts at hardrock mine sites in the U.S. As a general conclusion and recommendation, it is clear that regulatory review processes, such as EISs, should include an adequate analysis of baseline water quality, hydrological characterization and geochemical characterization and the full identification of appropriate mitigation and potential mitigation failures. The following sections provide conclusions and recommendations specific to the various failure modes identified in this study.

HYDROLOGIC CHARACTERIZATION

The case studies show the indirect cause and effect relationship between inadequacies in hydrologic characterization methods that were employed at mine sites and have resulted in impacts to water resources ranging from on-site contamination and contamination of headwaters streams to more extensive off-site contamination of surface water with the potential need for long-term water treatment in some cases. Hydrological characterization failures are most often caused by over-estimation of dilution effects, failure to recognize hydrological features (e.g., springs and shallow or perched groundwater) and underestimation of water production and stormwater quantities. Requiring adequate hydrological investigations as well as making conservative assumptions about water quality and quantity can address hydrological failures.

GEOCHEMICAL CHARACTERIZATION

The case studies show the indirect cause and effect relationship between inadequacies in geochemical characterization methods that were employed at mine sites and impacts to water resources. The severity of impacts ranged from on-site contamination and contamination of headwater streams to the need for long-term water treatment in some cases. Failure to identify the potential for contaminant leaching and acid drainage development has been a reoccurring theme at mine sites throughout the U.S. The case studies demonstrate the range of impacts to water resources that have occurred as a result of proper or adequate testing. The case studies also demonstrate that inaccurate geochemical predictions often lead to lack of identification of adequate mitigation measures.

Geochemical characterization failures can be addressed by emphasizing fundamental scientific requirements in the regulatory process. Such requirements should include adequate sample representation and testing, and interpretations that recognize the fundamental uncertainties and limitations of characterization testing. Improved geochemical characterization will lead to improved identification and of mitigation measures. As the most common characterization failure mode, the elimination of geochemical characterization failures can provide a large contribution to ensuring accurate water quality predictions and outcomes at hardrock mine sites.

MITIGATION

Waste rock mixing and segregation

At many mines, waste rock containing acid generating materials is managed by mixing and segregation practices. In most cases no data is available to ascertain the effectiveness of those practices, particularly where there is a significant distance from the source to water resources. The cases cited all have nearby water resources that were impacted. The data suggests that distance to water resources is potentially the most significant factor as to the effectiveness of waste rock mixing and segregation. Mitigation may depend more on climate and factors such as distance and geology affecting travel time and attenuation of contaminants. Where acid drainage generating materials are present, particularly in areas of headwater streams, waste rock mixing and segregation may not prevent impacts to water resources. These types of failures can be addressed by requiring adequate geochemical and hydrologic characterization and ensuring that segregated wastes are placed away from potential water pathways.

Liner leak, embankment failure or tailings spill

The case studies show that mitigation intended to capture contaminants such as liners and tailing impoundments may fail and lead to groundwater and surface water quality impacts. While in most cases, impacts are limited to on-site groundwater and nearby surface water, in some cases the impacts can result in more extensive surface water impacts and potentially to long-term water treatment. In all cases, additional mitigation, most often in the form of groundwater capture and treatment (including perpetual treatment in those severe cases), has resulted in effective capture and treatment of contaminants.

Failure of liners and tailing impoundments to perform is typically caused by design, construction and operational mistakes. These features frequently fail to perform, so it is important to consider the likelihood and consequences of those failures and to identify and implement additional mitigation that can be employed in the event of such failures. In many cases where initial mitigation has failed, such as mines where liner leaks have occurred, additional mitigation in the form of groundwater capture and treatment are often necessary. Additional consideration needs to be given to including groundwater capture and treatment systems as original designed mitigation for high risk features such as tailings impoundments containing cyanide in high risk (near surface water or groundwater) areas.

Land application discharge

The case study shows that land application, instead of acting as a disposal mechanism to facilitate zero discharge, can result in impacts to groundwater and surface water. The impacts demonstrated in this case study were recognized at other land application sites. With the exception of land application for the disposal of low-levels of nutrients that can be applied at agronomic rates, land application disposal has demonstrated a high rate of failure and significant impact at hardrock mine sites in the United States.

9. REFERENCES

Bolen, A.2002. Regulating the unknown: Pit lake policies state by state. Southwest Hydrology, Vol 1 #3, 22-23.

Coleman, J. 2004. Memorandum from John Coleman, Great Lakes Indian Fish and Wildlife Commission, to Neil Kmiecik, Biological Services Director. Re: Report on the status of the Flambeau Mine, February 22, 2004.

Council on Environmental Quality (CEQ), 1997, *The National Environmental Policy Act: A Study of Its Effectiveness After Twenty-Five Years.*

Dubois V. U.S. Department of Agriculture (1st Cir. 1996)

Enforcement History and Online Database (ECHO), http://www.epa.gov/echo/

Infomine (2004), http://www.infomine.com/

Kempton, H., and Atkins, D., 2000. Delayed environmental impacts from mining in semi-arid climates. Proceedings from the Fifth International Conference on Acid Rock Drainage, ICARD 2000, Volume 1. Published by the Society for Mining, Metallurgy, and Exploration, Inc., May 21-24, 2000, Denver, Colorado, pg. 1299-1308.

Kimmel, T., 2004, *GRG301K Weather and Climate Koppen Climate Classification Flow Chart*, www.utexas.edu/depts/grg/kimmel/GRG301/grg301kkoppen.html.

Koppen Climate Classification, 2004, www.geofictie.nl/ctkoppe2.htm.

Kuipers, James R., 2000, *Hardrock Reclamation Bonding Practices in the Western United States.* National Wildlife Federation, Boulder, CO, February 2000.

Lehrke, S. 2004. Memorandum from Stephen Lehrke, Foth & Van Dyke, to Jana Murphy, Flambeau Mining Company. Re: Flambeau Mining Company – 2003 Annual Report Groundwater and Surface Water Trends. January 1, 2004.

Maest, A., J. Kuipers, C. Travers, and D. Atkins. 2005. Predicting Water Quality at Hardrock Mines: Methods and Models, Uncertainties, and State-of-the-Art.

Mayer, K.U., Frind, E.O., and Blowes, D.W., 2002. A numerical model for the investigation of reactive transport in variably saturated media using a generalized formulation for kinetically controlled reactions. Water Resources Research #38.

Plumlee, G.S., 1999. The environmental geology of mineral deposits. Chapter 3 In: The Environmental Geochemistry of Mineral Deposits, G.S. Plumlee and M.J. Logsdon, eds., Rev. Econ. Geol. V 6A, Soc. Geol. Inc., Littleton, CO, 71-116.

Randol Mining Directory, U.S. Mines & Mining Companies (1990/1991, 1994/1995, 1999), Randol International Ltd, Golden, CO.

Robertson, A and Shaw, S, 2003. Risk Management for Major Geotechnical Structures on Mines, Vancouver, Canada.

Seal, R. R. II and Hammarstrom, J.M., 2003. Geoenvironmental models of mineral deposits: Examples from massive sulfide and gold deposits. Chapter 2 in: Jambor, J.L., Blowes, D.W., Ritchie, A. (Eds), *Environmental Aspects of Mine Wastes.* Mineralogical Association of Canada, Short Course Series, Vol. 31. pg. 11 – 50.

Appendix A
Major Mine Statistical Information

(available at www/kuipersassoc.com or http://www.mineralpolicy.org/publications_welcome.cfm)

Appendix B
Case Study Detailed Information

(available at www/kuipersassoc.com or http://www.mineralpolicy.org/publications_welcome.cfm)