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ESIA Review

Independent 3rd Party Assessment of the Impacts on Water Resources and Geology, Biodiversity and Air Quality

July 22, 2019

Amulsar Gold Mine
The Republic of Armenia

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ACRONYM LIST

Acidity	
ABA	Acid-Base Accounting
AMD	Acid Mine Drainage
AP	Potential Acidity
ARD	Acid Rock Drainage
NAG	Net Acid Generation
NPR	Net Potential Ratio
NP	Acid Neutralizing Capacity
Non-PAG	Non-Potentially Acid Generating
NNP	Net Neutralization Potential
PAG	Potentially Acid Generating
SAG	Strongly Acid Generating
WAD	Weak Acid Dissociable
Chemistry	
DO	Dissolved Oxygen
C	Carbon
$CaCO_3$	Carbonate
CaO	Lime
CO_2	Carbon dioxide
H	Hydrogen
HCl	Hydrochloric acid
K	Potassium
N	Nitrogen
NaCN	Sodium cyanide
NaOH	Sodium hydroxide
NH_4	Ammonia
NO_3	Nitrate
O	Oxygen
Fe	Iron
Fe(III)	Ferric Iron (Fe^{3+})
Fe(II)	Ferrous Iron (Fe^{2+})
S	Sulfur
Si	Silicon
Sr	Strontium
Geology & Hydrogeology	
ET	Evapotranspiration
K_h	Horizontal Hydraulic Conductivity
K_v	Vertical Hydraulic Conductivity

K_h / K_v	Hydraulic Conductivity Anisotropy Ratio
LV	Lower Volcanics
LVA	Lower Volcanic Andesite
VC	Upper Volcanics (*a.k.a.* UV)

Laboratory/Chemical Analyses & Testing

AAS	Atomic Absorption Spectroscopy
COC	Constituent of Concern
HC	Humidity Cell
ICP	Inductively-coupled Plasma
SPLP	Synthetic Precipitation Leaching Procedure
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
Wt.	Weight
Wt.%	Percentage by weight

Mining

ADR	Adsorption/Desorption/Recovery
BLS	Barren Leach Solution
BRSF	Barren Rock Storage Facility
GARD Guide	Global Acid Rock Drainage Guide
HL	Heap Leach
HLF	Heap Leach Facility
HLP	Heap Leach Pad
HLS	Heap Leach Solution
PLS	Pregnant Leach Solution
PSP	Pregnant Solution Pond

Miscellaneous

ASCE	American Society of Civil Engineers
ASL	Above Sea Level
ASTM	American Society for Testing and Materials
ATB	Amulsar Tectonic Block
EBRD	European Bank for Reconstruction and Development
ELARD	Earth Link & Advanced Resources Development
EMP	Environmental Monitoring Plan
RA	Republic of Armenia
ESIA	Environmental & Social Impact Assessment
EIA	Environmental Impact Assessment
GRE	Global Resource Engineering Ltd.
GSA	Groundwater Study Area
IBC	International Building Code

INAP	International Network for Acid Prevention
ICRA	Investigative Committee of the Republic of Armenia
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
ITRC	Interstate Technical & Regulatory Counsel (USA)
MNP	RA Ministry of Nature Protection
LCRS	Leak Collection and Recovery System
OM&M	Operation, Maintenance & Monitoring
PTS	Passive Treatment System
Q	Quarter
RA	The Republic of Armenia
SNCO	Environmental Monitoring and Information Center" of the RA MNP
SWWB	Site-Wide Water Balance
TOR	Terms of Reference (dated November 27, 2018 for this project)
TRC	TRC Environmental Corporation
UNDP	United Nations Development Programme
USEPA	United States Environmental Protection Agency
1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional

Biodiversity

ASCI	Areas of Special Conservation Interest
BOS	Biodiversity Offset Strategy
HIU	Habitats Impact Unit
IBA	Important Bird Area
IPA	Important Plant Area
JNP	Jermuk National Park
KBA	Key Biodiversity Area
NNL	No Net Loss

Air Quality

CO	Carbon Monoxide
DMRB	Design Manual for Roads and Bridges
HCl	Hydrochloric Acid
HCN	Hydrogen Cyanide
Hg	Mercury
MPC	Maximum Permissible Concentration
NOx	Nitrogen Oxides
PM	Particulate Matter
SO_2	Sulfur Dioxide
SOP	Standard Operating Procedure

TSP	Total Suspended Particles
WHO	World Health Organization

Units

km	kilometer
m	meter
mg/L	Milligram per liter
mm	millimeter
mM	milliMolar
mm/year	millimeter per year (mm/yr)
m^3	cubic meter
m^3/year	cubic meter per year

1.0 Introduction

Earth Link & Advanced Resources Development (ELARD) in association with TRC Environmental Corporation (ELARD-TRC Team) was retained by the Investigative Committee of the Republic of Armenia (ICRA), to conduct an independent, third-party assessment of the impacts of the Amulsar Mine on water resources and geology, biodiversity and air quality. The Amulsar Mine ("Site", "Mine", or "Project") is located in central south-east Armenia and is being developed by Lydian International (Lydian).

This Report presents the results of ELARD-TRC Team's assessment of Amulsar Mine's impacts on water resources, geology, biodiversity and air quality pursuant to the November 27, 2018 Terms of Reference (TOR).

1.1 Objectives

Pursuant to the TOR, the objectives of the Independent Assessment are to:

On Water Resources and Geology:

- Evaluate the extent, methodologies, and scientific rigor of data collection, and the reliability of the conclusions of the Environmental and Social Impact Assessment (ESIA; version 10; June 2016) and Environmental Impact Assessment (EIA) related to water and geology;
- Evaluate the appropriateness of ESIA/EIA assessment of risks on water resources and geology and the appropriateness of proposed monitoring and mitigation measures including effectiveness and compliance with local regulations and international standards;
- Assess data gaps and their impacts on the methodologies of the ESIA/EIA; and
- Provide responses to specific questions included in the TOR.

On Biodiversity:

- Understand and evaluate the impacts of the project on natural habitats and biodiversity;
- Conduct a due diligence study of the existing EIA to ascertain compliance with international standards on preservation and conservation of biodiversity;
- Evaluate the conservation status of patrimonial species (endemic, vulnerable, rare) including *Potentilla Acantholimon* and *Parnassius* among others; and
- Assess the measures proposed for reduction/avoidance of ecological impacts from the project.
- Provide responses to specific questions included in the TOR.

On Air Quality:

- Review the adequateness of the data used to assess the air quality impacts;
- Evaluate the appropriateness of the ESIA/EIA assessment of the impacts from dust generation and its possible health effects taking into account where relevant the chemical composition of dust and the health impact on the surrounding community;
- Evaluate the appropriateness of the air dispersion modeling studies;
- Evaluate the adequacy of the mitigation measures proposed;
- Provide responses to specific questions included in the TOR.

1.2 Scope of Assessment

Pursuant to the TOR, this assessment is mainly based on relevant ESIA and EIA sections and environmental monitoring reports generated since 2016. The Team also reviewed relevant reports prepared by others and data obtained from the Ministry of Nature Protection (MNP) and from internet search and from other experts.

ELARD-TRC Team conducted the following activities:

- Visited the Republic of Armenia during March 26 through 30, 2019 and met with and gave presentations about the scope, goals, and expectations of the Independent Assessment to representatives of ICRA, MNP, and experts from various RA institutions.
- Attended a presentation on Water Resources on March 28, 2019 by Lydian and its consultants including Global Resource Engineering (GRE) and Golder Associates (Golder) about the Amulsar Mine.
- Conducted a Site visit along with representatives of ICRA, MNP, Lydian, GRE, and Golder on March 29, 2019 and observed some of the existing partial structures and facilities.
- Visited Lydian's laboratory on March 29, 2019, where the Team observed rock cores and attended a presentation by Lydian about the bench scale bio-treatability testing.
- Attended through Skype a presentation on Air Quality by Lydian and its consultants on April 5, 2019.
- Attended through Skype a presentation on Biodiversity by Lydian and its consultants on April 9, 2019.
- Provided questions to Lydian and received Lydian's responses via ICRA in April 2019.
- Submitted to ICRA a Partial Draft Independent Assessment Report dated May 31, 2019.
- Submitted to ICRA a Draft Independent Assessment Report dated June 14, 2019.
- Presented the findings of the Independent Assessment to HE the Prime Minister, ICRA and MNP representatives in Yerevan on June 20 and 21, 2019.

- Participated in a conference call related to water and geology with ICRA, MPN, and Lydian's representatives on June 27, 2019 regarding Lydian's comments about the June 14, 2019 Draft Assessment Report.

- Participated in a conference call related to biodiversity and air quality with ICRA, MPN, and Lydian's representatives on July 1st, 2019 regarding Lydian's comments about the June 14, 2019 Draft Assessment Report.

- Reviewed comments received via ICRA from Lydian on June 28, 2019 (on water and geology) and July 4th (on biodiversity and air quality) about the June 14, 2019 Draft Independent Assessment Report.

- Reviewed Lydian's responses received via ICRA on July 3, 2019 to questions provided on June 28, 2019 by ELARD-TRC Team about geochemical data and mitigation measures.

- Submitted a Final Independent Assessment Report dated July 22, 2019.

1.2.1 Assessment of the Impacts of Geology

Pursuant to the TOR, the objectives of the review are to:

- Understand and evaluate the scientific basis of Lydian's claim that the Amulsar block is an isolated geologic block;
- Evaluate the geophysical, geotectonic, and geochemical data for the Site and the methodology employed for the ESIA; and
- Assess the geochemical studies of Amulsar ores.

1.2.2 Assessment of the Impacts on Water Resources

Pursuant to the TOR, the main objectives of the review are to:

- Evaluate the potential impacts on water resources (surface water and groundwater) from various project activities during construction, operation, and post-closure; and
- Evaluate the proposed mitigation measures in the ESIA report for the Site.

The main concerns are potential impacts to:

- The Jermuk Springs, including the hydrothermal springs;
- The Spandaryan-Kechut tunnel and Kechut reservoir, which feeds Lake Sevan;
- Water supply sources for the seven communities within the vicinity of the mining facility;
- Various springs, especially those located on the flanks of the mine pits, near the Barren Rock Storage Facility (BRSF), and in vicinity of the Heap Leach Facility (HLF); and
- The Arpa, Darb, and Voratan Rivers.

The review entails assessment of the following items:

1. Lydian's evaluation of the existing hydrologic and hydrogeologic regime of the project area as part of the ESIA baseline assessment, including identification and hydraulic characterization of the subsurface and groundwater interaction with surface water; spring sources and emergence mechanisms; connections between various basins, especially with the Jermuk basin, and with the underlying deep aquifer system;

2. The adequacy of key groundwater data that were used in the assessment, including water isotopic, chemical, geochemical, and meteorological data, and surface water flow data;

3. The groundwater model developed for flow and contaminant transport predictions;

4. The water balance estimation for the prediction of surface water runoff;

5. The identification and characterization of potentially acid generating rock (PAG) and the assessment of the impacts of acid-rock drainage (ARD) on existing water resources; and

6. The adequacy of proposed environmental mitigation measures for the protection of water resources during normal operation and catastrophic events.

1.2.3 Assessment of the Impacts on Biodiversity

Pursuant to the TOR, the main objectives of the review are to:

- Understand and evaluate the impacts of the project on natural habitats and biodiversity;

- Conduct a due diligence study of the existing EIA to ascertain compliance with international standards on preservation and conservation of biodiversity;

- Evaluate the conservation status of patrimonial species (endemic, vulnerable, rare) including *Potentilla Acantholimon* and *Parnassius* among others; and

- Assess the measures proposed for reduction/avoidance of ecological impacts from the project.

1.2.4 Assessment of the Impacts on Air Quality

Pursuant to the TOR, the main objectives of the review are to:

- Review the adequateness of the data used to assess the air quality impacts;

- Evaluate the appropriateness of the ESIA/EIA assessment of the impacts from dust generation and its possible health effects taking into account where relevant the chemical composition of dust and the health impact on the surrounding community;

- Evaluate the appropriateness of the air dispersion modeling studies;

- Evaluate the adequacy of the mitigation measures proposed.

1.3 Bases and References

The assessment and conclusions in this report have been developed to a reasonable degree of scientific certainty based upon our review of:

- Relevant sections and appendices of the ESIA;
- English-translated sections of the EIA (provided in April-May 2019);
- Various ESIA model input data, technical memoranda, and studies prepared for the Site to assess impacts on water resources;
- Environmental monitoring reports and data;
- Relevant scientific reports from local experts;
- Published scientific articles and studies or information obtained via internet search;
- Data about the geology and water resources of the region provided by the MNP and ICRA;
- Amulsar Mine satellite geologic images;
- Lydian's responses to specific inquiries from ELARD-TRC Team and Lydian's comments on the June 14, 2019 Draft Report received via the ICRA;
- Relevant RA regulatory requirements; and
- Our knowledge of applicable requirements for similar sites, and standard practice guides.

Specific references that are cited in this report are listed in Section 5.0.

We understand the assessment may be limited because ELARD-TRC Team may have not been provided or may have not reviewed all the relevant information, data, and analyses. We reserve the right to amend our report and supplement our conclusions expressed herein as additional information becomes available.

1.4 Qualifications of Experts

- **Nidal Rabah**, PhD, PE, LSRP, PMP is a Vice President and the Director of Technical Development and Center of Research & Expertise (CORE) at TRC in New Jersey, USA. Dr. Rabah is a Licensed Professional Engineer, Licensed Site Remediation Professional, and Certified Projection Management Professional with more than 30 years of professional and academic experience with focus on advanced characterization, innovative remedial technologies, groundwater modeling, and water resources planning and development. He led numerous large-scale environmental assessments, remediation, and construction projects. He served on the Interstate Technical & Regulatory Counsel (ITRC) Remediation Management of Complex Sites Guidance team and authored and co-authored over 25 technical publications. He serves as a technical expert on environmental claims.

  He serves as a Technical Director and Lead Environmental Engineer on the assignment related to Water Resources and Geology.

- **David Hay**, PhD, CPG is a Principal Hydrogeologist and Geochemist at TRC in Colorado, USA. Dr. Hay is a Certified Professional Geologist with more than 30 years of experience with focus on hydrogeologic and hydrologic characterization and testing, geochemistry and geochemical modeling, groundwater flow and contaminant transport modeling, mining characterization and remediation, and coal and oil/gas exploration and development. He was a member of the ITRC Guidance Teams for Characterization and Remediation of Fractured Rock and LNAPL. He has authored and coauthored over 20 technical papers and presentations. Dr. Hay is listed in TRC's national register of experts and is a member of several TRC CORE teams.

He serves as a Lead Hydrogeologist and Geochemist on this assignment.

- **Robert Stanforth**, PhD is a Senior Geochemist and Wastewater Treatment Expert at TRC in Wisconsin, USA. Dr. Stanforth has more than 30 years of professional and academic experience, with focus on hazardous waste treatment and environmental analysis. His areas of expertise include evaluating waste leaching characteristics, developing and applying treatment technologies for hazardous wastes and heavy metals, and developing and implementing wastewater treatment methods, and development and implementation of wastewater characterization analytical methods and laboratory treatability testing. He holds 11 patents on methods for treating hazardous waste and heavy metal leaching from soil or waste and has authored and presented over 60 technical papers. Dr. Stanforth is listed in TRC's national register of experts and is a member of TRC CORE teams.

  He serves as a Geochemist and Wastewater Treatment Specialist on the assignment related to Water Resources and Geology.

- **Ramez Kayal**, MSc is the President and a Principal Geologist/Hydrogeologist at ELARD Lebanon with more than 30 years of professional experience on conducting hydrogeological assessment, groundwater vulnerability studies, groundwater modeling as well as soil and groundwater remedial investigations. Mr. Kayal has extensive experience in working in mountainous regions and assessing impacts of projects on water resources.

  He serves as peer reviewer on the assignment related to Water Resources and Geology.

- **Carla Khater**, Ph.D., is a senior ecologist with more than 15 years of experience in ecosystem management and restoration ecology.

  She serves as a biodiversity expert and coordinator on the assignment related to Biodiversity.

- **Alexandre Cluchier** graduated from the French Sorbonne, Paris, and the University of Montpellier, in France; he is a Senior International Ecologist Expert and Advisor for project owners and governments with 20 years experience in biodiversity assessments as part of Environmental Impact Assessments for projects throughout Europe, Africa, the Middle East and the Caribbean area.

  He serves as a biodiversity expert on the assignment related to biodiversity.

- **Charbel Afif**, PhD is a Senior air quality expert. Dr. Afif has over 15 years of professional and academic experience. His areas of expertise include emissions estimation and treatment, measurements and metrology of air pollutants, design of air quality monitoring networks, air dispersion modeling, and design of air quality strategies. He has authored and coauthored over 70 technical papers and presentations.

  He serves as an Air Quality Expert and lead author of the assignment on Air Quality.

- **Ricardo Khoury**, ME. is a senior environmental specialist with more than 22 years of experience managing complex ESIA studies. He often supports international financing institutions, governments and project developers in developing bankable ESIA studies for projects in various sectors including mining, oil and gas, renewable energy, and public infrastructure among others.

  He serves as overall study coordinator and peer reviewer of biodiversity and air quality assignments.

1.5 Structure of the Report

This report is structured in a way to align with the Armenian Legislation related to such reports. It includes:

- An Introduction (Section 1)
- The Examination sub-divided in three sub-parts (Water and Geology, Biodiversity and Air Quality) (Section 2)
- Summary, Conclusions and Data Gaps (Section 3)
- Responses to Specific ToR questions (Section 4)
- References (Section 5)
- Appendices

2.0 Examination

2.1 Water and Geology

2.1.1 Baseline Characterization

Figure 4.1.4 of the ESIA (Wardell Armstrong, 2016) depicts the outline of the environmental baseline study area. In this report, this area is referred to as the Project Area as a general descriptor of the Amulsar Mine and vicinity.

2.1.1.1 Meteorological Data

Elevation strongly influences climatic conditions, including precipitation, temperature, and solar radiation. Elevation, therefore, is a key consideration in choosing a meteorological station for acquiring climate data. Other considerations are the period of record and completeness of data.

2.1.1.1.1 State

Two State meteorological stations are located near the Project Area. One station is in Jermuk, and the other station is on Vorotan Pass. The Vorotan Pass station is approximately 325 m higher than the Jermuk station. The mine pits are considerably closer to the Vorotan Pass station than Jermuk, and the elevations of the pits are closer to the Vorotan Pass station elevation than Jermuk (ESIA Table 4.2.1). The BRSF is 1 km closer to Jermuk than the Vorotan station, but the elevation of the BRSF is closer to the elevation of the Vorotan station. The elevation of the HLF is closer to the elevation at Jermuk, which is less than 1 km farther than the Vorotan station. These data suggest the Vorotan Pass station may have the most appropriate climate data for analyses related to the mine pits and the BRSF, and the Jermuk station data would be better suited for analyses concerning the HLF.

The Vorotan Pass station record is continuous for most measurements for 51 years, from 1962 to 2013. Use of these data are appropriate for all analyses, except potentially for the HLF analyses. Appendix 4.2.1 of the ESIA states that there are appreciable differences between the Vorotan Pass and Jermuk stations in the values of precipitation, evaporation, and temperature, as well as for snow depths and accumulation periods.

The Vorotan data were chosen for the baseline dataset. Section 4.2 of the ESIA states that the trends in Jermuk data are similar to Vorotan data. The period of record at Jermuk, however, is only 22 years, from 1992 to 2013. The Jermuk data were used for the updated Project Water Balance (Golder, 2018). Any other analyses for the HLF using Vorotan climate data are considered suspect.

2.1.1.1.2 Site

An on-site weather station, Capricorn-Columbia, is located on the southeastern edge of the BRSF. The period of record is short (2009 – 2011) and incomplete, but the data are purportedly comparable to the Vorotan Pass data.

2.1.1.1.3 Data Manipulation

The Vorotan Pass climate data were analyzed to develop an average climate year, extreme dry and extreme wet years, and typical dry and typical wet years (ESIA Tables 4.2.4 and 4.2.5). The average, extreme dry, and extreme wet years represent the statistical mean and the corresponding minimums and maximums of precipitation and evaporation data. The typical dry and typical wet years, however, are based on a set of arbitrary assumptions. Rather than developing these so-called typical years, which are intended to produce a range of modeling results, a statistical approach is more defensible. For example, the 25th and 75th percentiles of precipitation and evaporation could be used in the modeling.

2.1.1.1.4 Climate Trends

Golder (2016c) made seasonal adjustments to the baseline climate information for the purpose of assessing the potential impacts that climate change may have on the results of evaluations using the baseline data. The adjustments are partly based on the 2014 projections for the Project region by the Intergovernmental Panel on Climate Change (IPCC) that used global climate models. The adjustments also reflect localized projections using a downscaled climate change model (UNDP Armenia), summarized in the Environmental and Social Impact Assessment for the Amulsar Gold Mine Project. The adjustments, which are relevant through 2030, are summarized in Golder (2016c Table 11). Temperature is adjusted for an increase of 1^{o}C from September through February and 2^{o}C from March through August. Precipitation is adjusted for a decrease of 11% from December through May, a decrease of 9% from June through August, and an increase of 5% from September through November. The adjustments have not yet been incorporated in any evaluations. Golder's (2018) updated Site-Wide Water Balance (SWWB), for example, is based on historical climate data.

Melkonyan and Gevorgyan (2017) analyzed historical climate data from numerous meteorological stations in Armenia for trends that may be indicative of future climatic conditions. Their results indicate that the Golder (2016c) adjustments in temperature and precipitation are consistent with trends for Armenia in general. However, the Melkonyan and Gevorgyan (2017) analyses for different elevations show that decreases in precipitation at elevations corresponding to the Project area are much less than Armenia in general (i.e., from 2,000-2,500m -0.8% and 2,500-3,000m -2.2%). They also concluded that climate risks and the frequency of hazardous hydrometeorological events have increased due to changes in the global atmospheric circulation.

2.1.1.2 Geology and ARD Geochemistry

2.1.1.2.1 Regional Setting

The regional geology is described in Section 4.6.1 of the ESIA. The Amulsar ore deposit is located in south-central Armenia in the Lesser Caucasus Mountains. The description of the regional geologic setting, including ore host rocks generated in a calc-alkaline magmatic arc system and the proximity of the Project Area to the suture zone associated with closure of the Neo-Tethyan Ocean, was verified by an independent literature search[1] (*e.g.,* Adamia *et al.,* 2011).

The description in Section 4.6.1 is brief, but sufficient, and includes a few regional geologic maps (ESIA Figures 4.6.1 and 4.6.2) that convey the essence of the tectonic setting. The information is also supported by documents provided by ICRA (Grosjean *et al*., 2018; Holcombe *et al*., 2013).

[1] The reference cited in the ESIA was unavailable.

2.1.1.2.2 Local Geologic Model

The description of the local geology in Section 4.6.2 of the ESIA is based on the work of Holcombe *et al.* (2013) and Holcombe (2013). The following summary of the local geology (excluding the Amulsar Tectonic Block) is a synthesis of key points from the original documents, augmented by relevant information from Oliver (2013), who contributed to an understanding of the sequence of events in the geologic history leading to ore deposition.

2.1.1.2.2.1 Rock Types, Stratigraphy, and Distribution

The Project Area is underlain by a very thick sequence of Paleogene volcano-sedimentary rocks. The rocks flanking the ore deposit consist of multiple fining-upward cycles of volcanogenic conglomerate and mass flow breccia, with marly mudstone and, locally, thin calcilutite limestone. The composition of the volcanic rocks is andesitic to dacitic. Some of the andesitic rocks are porphyritic and were interpreted to be intrusive (Oliver, 2013), as well as thick lava flows. The flanking strata are sub-horizontal to gently dipping and locally cut by steep faults. Scattered intermediate to silicic composition plutons and dikes occur in these rocks within and adjacent to the Project Area. At the lower elevations to the east and west of the Amulsar Mountain ridge and covering the northern face of the ridge, basalt lava flows post-date and overlie the Paleogene volcano-sedimentary and intrusive rocks, forming plateaus along the banks of the Vorotan and Arpa River gorges. Colluvium overlies the bedrock throughout much of the Project Area, with a thickness ranging from less than 1 m up to 20 m (ESIA Section 4.8)[2].

The Paleogene volcano-sedimentary rocks are subdivided into Upper Volcanics (VC/UC) and Lower Volcanics (LV). The VC and LV are described as follows (paraphrased from the ESIA):

- **VC**: Sparsely-bedded volcanogenic conglomerate, feldspathic sandstone, and minor siltstone which are interbedded with abundant thin and thick lenticular debris flows, minor andesitic lava flows, and volcanogenic/volcaniclastic breccia. Debris flows are dominated by pebble- and cobble-size breccia with sparse boulder-size components.

- **LV**: Dominantly feldspar-porphyritic andesite at high elevations, generally without flow characteristics, considered likely to have been intruded in the volcanic edifice. Subordinate rocks include feldspar and amphibole-porphyritic andesite, rocks with pebble- to cobble-size fragments, and indeterminate rock types. The volcano-sedimentary rocks described in the first paragraph of this sub-section crop out at lower elevations.

The VC crop out high on Amulsar Mountain and its eastern flank. Underlying the VC are extremely thick LV, which crop out all around Amulsar Mountain, extending from high elevations on the west side of the mountain to the gorge of the Arpa River. Noteworthy is the lumping of the porphyritic andesite with the LV. According to Oliver (2013), most of the porphyritic andesite post-dates deposition of both LV and VC.

2.1.1.2.2.1.1 Alteration

The gold deposit is associated with a zoned alteration largely controlled by rock type (Oliver, 2013). The distinguishing feature of the VC is pervasive silicification and strong alunite alteration. The silicification occurred preferentially in the volcaniclastic and clastic rocks. In

[2] Section 4.6.2 of the ESIA indicates the colluvium thickness ranges up to 30 m.

contrast, the LV is distinguished by pervasive argillic alteration in the region of the orebodies, grading to unaltered rocks with distance. Geoteam (2014) states that the argillic andesitic rocks are homogeneous and unbroken.

The ore deposit is interpreted to have evolved from a local volcanic edifice (Holcombe *et al.,* 2013). Oliver (2013) interpreted a long history of silicification that may have begun prior to deposition of some of the volcaniclastic units. After sill intrusions of chemically distinct porphyritic andesite, further epithermal-style hydrothermal alteration occurred as proximal silicification, primarily affecting the VC, and distal, widespread quartz-sericite-pyrite (phyllic) alteration in the porphyritic andesite. Subsequently, with waning fluid temperatures, strong argillic and local alunite alteration occurred in the porphyritic andesite (overprinting phyllic alteration) and the LV, accompanied by local alunite and clay alteration in the upper volcanics around veinlets and contacts. Gold and hematite mineralization overprints all these alteration stages, and primarily occurs in the silicic VC. A late supergene weathering stage produced limonite and alteration of hematite to goethite.

2.1.1.2.2.2 Structure

The Amulsar gold deposit occurs within a ridge that is locally structurally-complex and purportedly surrounded by regionally simple structure characterized as sub-horizontal to gently dipping strata with little internal structure, except offsets produced by high-angle faults. Within the complex mineralized zone, the silicic VC is underlain by and interleaved with the argillically-altered LV and porphyritic andesite. Multiple stratiform panels of the clay-altered porphyritic andesite occur within the VC sequence, and these panels have complex fold geometries. Most of the andesite panels are believed to be intrusive sills, but the interleaving is at least partly structural (resulting from imbricate thrusting).

The silicic VC rocks and the argillic andesite panels only occur above a stratiform structural level called the basal contact. Below this contact, only argillic rocks were encountered during drilling, and the rocks immediately below the basal contact are the same porphyritic andesite as the interleaved panels. Above the basal contact, stacked sheets of the argillic porphyritic andesite have been locally observed with evidence of fault contacts (imbricate thrust faults). Locally, the thick lower andesite sheets and the basal contact are folded into a broad antiform.

The subdivision of the Paleogene volcano-sedimentary rocks into VC and LV derives from stratiform nature of the base of the VC. The basal contact has been referred to as a disconformity (e.g., ESIA Section 4.6.1), but the occurrence of the same argillic andesite above and below the contact negates this interpretation.

Prior to mineralization, an interpreted large overturned fold was breached by several thrust faults. Syn-mineralization deformation, including local thrust faulting and possibly dextral wrenching, refolded and offset older structures. The most prominent post-mineralization structures that overprint older structure are NE-trending normal faults that cross the ridge obliquely and delimit a series of horsts and grabens.

On the western side of the ridge, the lowest observed contact is a west-dipping, low-angle semi-ductile fault zone, with steeply dipping, locally folded VC rocks overlying the argillic LV rocks. This contact is believed to be an early northeast-directed thrust fault (Orontes Thrust). This structure was mapped through the horst block between Tigranes and Erato, and an east-dipping mylonitic zone on the eastern flank of the ridge is suggested to be structurally related.

Peripheral to the complex ridge structure, the structure is purportedly comparatively simple. Strata are sub-horizontal to gently dipping, and silica-altered VC rocks overly argillically-altered LV rocks. On the eastern side of Amulsar Mountain, the contact between the argillic LV rocks and the silicic VC rocks occurs at an undeformed stratiform contact (basal contact).

2.1.1.2.2.2.1 Amulsar Tectonic Block

The location and characteristics of the Amulsar Tectonic Block (ATB) are described in Geoteam (2014) and GRZ (2011). According to these documents, the Project Area is located in the ATB, a central autonomous tectonic block comprised of an Eocene-Oligocene volcanic dome, and the ATB is located in the interfluve area of the Arpa, Vorotan, and Darb Rivers. The ATB is triangular, bounded entirely by three major tectonic faults that intersect, the Kechut Fault, the Agarakadzor Fault, and the Zirak Fault.

The Geological Map of Vayots Dzor (Armenia) is included in the Geoteam (2014) document. Based on this map (includes fault traces), descriptions of the locations of the faults in GRZ (2011), and a physiographic map[3] showing the Mine and faults in the vicinity of the Project Area (Appendix A of this report), the faults were identified and labeled on the Geologic Map of Vayots Dzor (Appendix A of this report). Relevant descriptive information about the faults in GRZ (2011) are combined in the following paragraph with observations about the traces of the faults on the geologic and physiographic maps.

The Agarakadzor Fault is a major structural zone (up to 1 km wide) that intersects the Kechut Fault at or near the confluence of the Arpa and Darb Rivers and passes near and/or along the Darb River gorge to Vorotan Pass and is projected to intersect the Erato Pit, the Zirak fault, and the Vorotan River Valley. The Kechut Fault, one of the largest faults in the region, is a northeasterly striking structure (up to several hundred meters wide) that intersects the Agarakadzor Fault as noted and passes near and/or along the Arpa River Valley to Kechut Village and beyond. The Zirak Fault is oriented northwest-southeast, intersecting the Kechut Fault before passing beneath the Kechut Reservoir then through the Zirak Volcano, intersecting the Agarakadzor Fault, and passing beneath the Vorotan River. These three faults are visible and mapped on satellite imagery of SOYUZ 6 and ERTS-NASA. Hydrothermal alteration is associated with all three faults, structural deformation with the Kechut and Agarakadzor Faults, intrusive igneous rocks with the Kechut and Zirak Faults, and mineral springs with the Kechut Fault. According to Geoteam (2014), the Zirak Fault is clearly visible on the ground surface.

According to GRZ (2011) and Geoteam (2014), the ATB is autonomous (independent or isolated) due to its hydrogeological characteristics. They state that the ATB is not connected to adjacent regions, and the Mine cannot impact the hydrogeology and water quality, including mineral and fresh water springs, of the regions adjacent to the ATB, particularly the Jermuk mineral springs. Similar statements are included on the Lydian web page.

2.1.1.2.2.3 Mineralization

The Amulsar gold deposit does not conform to any simple type-classification (Oliver, 2013). The mineralization is most analogous to Chilean low-temperature, low-sulfur, iron oxide-copper-gold systems, which have alteration haloes similar to low to intermediate sulfidation epithermal systems. The deposit is structurally-controlled, oxidized, and low temperature hypogene, with a

[3] Included on web page of Lydian Armenia describing the mine and the ATB.

supergene overprint of limonite and goethite. The gold has a strong association with iron, copper, arsenic, antimony, bismuth, and lead, and is surrounded by, and largely overprints, a halo of variably phyllic-argillic-silicic altered volcanic rocks and intrusive porphyritic andesite. The structural association of gold is dominated by the infilling of faults and fractures and mosaic to chaotic breccias. Some of these breccias are fault-related hydrothermal breccias, but others show evidence for diatreme-like brecciation and coincident high-grade gold deposition. Quartz dominates the mineralogy of the ore occurrences, with hematite, limonite, and goethite, and minor rutile, chlorite, mica, alunite, and jarosite. A significant pre-history to the gold deposition includes the development of zoned alteration, largely controlled by rock type, with the earliest silicification probably occurring prior to the deposition of some of the volcaniclastic units.

2.1.1.2.2.4 Assessment of the ESIA Characterization of Local Geology

The geologic characterization work in the Project Area was focused on the high elevations of Amulsar Mountain in the vicinity of the ore deposits and the BRSF. The rest of the area bounded by the three rivers is only superficially described. Drawing 4.8.1 of the ESIA shows groundwater level monitoring locations for several other areas, where presumably subsurface geologic data were obtained, yet there are no cross-sections across the Project Area to depict the stratigraphy and structure. Cross-sections from the 3-D geologic model (Holcombe, 2013) only show the geologic relationships in the vicinity of the ridge (pits area). If geologic data are lacking for areas beyond the ridge or were obtained but not integrated into the conceptual model, this deficiency translates to poor understanding of the subsurface between sources and receptors of groundwater contaminants. For such an environmentally-sensitive area, the omission of illustrations of the structural and stratigraphic relationships across the Project Area is a serious shortcoming in the ESIA conceptual model. The conceptual geologic model is the basis for models that numerically represent groundwater flow and contaminant transport.

The ESIA description of the local geology is disorganized, incomplete, and incomprehensible without reading the original documents. The text gives the impression of poorly understood structural and stratigraphic relationships, distribution and causes of alteration types, and the sequence of events in the genesis and occurrence of the various rock types along the ridge. The text also seems unclear as to whether all the rock types and alteration types are characterized for ARD. One omission in the distinction and delineation of rock types is the widespread phyllic alteration. This phyllic alteration was apparently lumped with the argillic alteration, which is a local overprint on the earlier phyllic alteration. The text and illustrations, supported by the cited references, portray isolated complex structure of the ridge and geologic simplicity of the rest of the Project Area. This conceptualization is unrealistic given the occurrence of folds and thrusts on the ridge and the existence of bordering rivers that are structurally controlled.

The thrust and wrench faults mapped in the mineralized zone are manifestations of widespread crustal shortening related to collision of the Eurasian and Africa-Arabian lithospheric plates (Adamia *et al*., 2011). The faults are not limited to the ridge in the Project Area. The existence of the ridge and good exposure of structures may be partly due to the resistance of the silicic rocks to erosion. The imbrication identified on the ridge suggests structurally lower sub-parallel thrusts and folds occur in the Project Area. Holcombe (2013) suggested that the Orontes Thrust, the deepest low-angle structure identified on each side of the ridge and mapped through the horst block between Tigranes and Erato, is lying piggyback on another thrust fault at depth. High-angle faults mapped in the mineralized area also occur across the Project Area.

Detailed surface geologic mapping is lacking for the remainder of the Project Area. Faults are only delineated in the vicinity of the mineralization (ESIA Figures 4.6.3 and 4.6.7). One explanation for the absence of faults on surface geologic maps is that little effort was expended beyond the area of economic interest.

Faults may be barriers and/or conduits of groundwater flow. Furthermore, volcanic rocks are brittle, with widespread fracture permeability, including bedding-plane fractures. These characteristics influence groundwater flow and transport rates. The argillic rocks cannot be assumed to be a homogeneous clay zone, void of fractures. In fact, the processes associated with deposition of the ore superimposed brecciation on the altered rocks. Fracturing beyond the mineralized zone is not described in Section 4.6.2 of the ESIA or supporting documents on the geology, suggesting surface and borehole fracture characterization was not performed. The omissions of fault mapping and fracture characterization represent data deficiencies for conceptualization of the controls on groundwater flow paths and rock transmissivities. Correct numerical model representations of groundwater flow and solute transport from the pits and project facilities to receptors (rivers and springs) are dependent on the structure and characteristics of the rock throughout the flow and transport paths.

The Project Area is only partially encompassed by the ATB (Appendix A of this report). The entire Tigranes-Artavasdes-Arshak pit area and at least part of the Erato Pit are south of the Agarakadzor Fault and the ATB. Moreover, the BRSF straddles the trace of the Zirak Fault, with parts of the BRSF being north of the fault and the ATB. A large part of the Kechut Reservoir is within the ATB near its northern vertex. Potential seepage to groundwater from the part of the BRSF north of the Zirak Fault could result in contaminated groundwater reaching the Madikenc springs. Contaminated groundwater below the mine pits can flow to the Darb and Vorotan Rivers.

The locations of the Darb and Arpa Rivers are structurally controlled, and rivers are commonly hydraulic boundaries (no groundwater flow across the plane of vertical projection). Furthermore, faults may be barriers to groundwater flow, and the hydrothermal alteration increases the likelihood that the faults are barriers to groundwater flow. However, with part of the BRSF and most of the mine pit areas outside the ATB, it is incorrect to state that the mine cannot impact regions (including fresh water springs) adjacent to the ATB. Additionally, faults may be conduits of groundwater flow. Under such a setting, the Agarakadzor fault could conduct contaminated groundwater to the Darb and Arpa Rivers. Similarly,the Zirak Fault could conduct contaminated groundwater, including potential seepage from the BRSF (elevation approximately 2,600 m), to the Kechut Reservoir (elevation approximately 1,950 m) and/or the Vorotan River (elevation approximately 2,200 m at the projected intersection of the Zirak Fault).

Surface water and groundwater moving northward from the BRSF follow northwest trajectories toward the Arpa River and the Kechut Reservoir. Jermuk is at least 1,000 m higher than Kechut Reservoir. The Arpa River flows southward from Jermuk then southwestward from the Kechut Reservoir. The elevation of the river valley decreases to 1,400 m at the confluence of the Darb and Arpa Rivers. Groundwater potentials also decrease along the river valley in the direction of river flow. Furthermore, there is a northeast-oriented tributary to the Arpa River between Jermuk and the Mine facilities, which is a probable hydraulic boundary. Even with part of the BRSF being north of the Zirak Fault, seepage from the BRSF will not reach Jermuk. Finally, Jermuk is northwest of the trace of the Kechut fault, which may also be a barrier to groundwater flow.

2.1.1.2.3 ARD Potential - Acid Generation and Metals Leaching Potentials

Sources of potential environmental impacts related to the geology of the Project include pit walls, adits, barren waste rock (including pit backfill), a low-grade ore stockpile, and spent ore in the heap leach pile. Section 4.6.5 and Appendix 4.6.2 (GRE, 2014d) of the ESIA summarize the ARD characterization for the Project. Characterization of the potentials for ARD, leaching of metals, and generation of other constituents of concern (COCs) was performed for two basic rock types, VC and LV, and colluvium. Subsequently, an ARD block model was developed (GRE, 2018b) to determine the quantity and distribution of potentially acid generating (AP) waste rock.

Figures 4-1 and 4-2 of Appendix 4.6.2 of the ESIA show the distribution and density of sampling in the Tigranes/Artavasdes and Erato pit areas, respectfully. Table 4-1 of Appendix 4.6.2 (GRE, 2014d) shows the types and numbers of characterization tests performed on barren rock and spent ore from each pit area and borrow materials. The characterization tests are acid-base accounting (ABA), net acid generation (NAG) pH, bulk chemistry, mineralogy, synthetic precipitation leaching procedure (SPLP), NAG effluent, and humidity cell (HC).

2.1.1.2.3.1 Characterization Methods

Extensive characterization should be performed for each geochemical test unit. Geochemical test units are rock types of distinctive lithology, mineralogy, and/or alteration (*e.g.,* Maest *et al.,* 2005). The units should be as homogeneous as possible based on lithology, mineralogy, alteration, and the extent of exposure of minerals to weathering. Depending on the results of the characterization, some of the test units may be combined, or it may be necessary to subdivide them for waste management purposes.

2.1.1.2.3.1.1 Mineralogical Analyses

Mineralogical data are an essential component of ARD characterization because the mineralogical properties determine the physical and geochemical stability and reaction rates of geologic materials and mine wastes (*e.g.,* INAP, 2009). The types of mineral phases indicate the major chemical constituents and relative reaction rates. Surface exposure, grain size, and deformities also affect reaction rates. One of the most important uses of mineralogical data is support for and design of other tests and interpretation of the results. Mineralogical analysis is typically required for a representative sub-set of the static test samples and each kinetic test sample. Mineralogical data indicate which minerals likely contributed to test results and the likelihood they will contribute similarly in the natural environment. Representative samples are based on a good understanding of the geology and geochemical variability (e.g., alteration types) from previous analytical work related to exploration. At a minimum, visual identification of minerals in core, petrographic analysis (transmitted and reflected light), and X-ray diffraction (XRD) should be performed.

Whole Rock Geochemistry

Whole rock analysis (bulk chemistry) determines the total concentrations of constituents in a rock sample. These data assist in identifying constituents of concern, but they are not a measure of potential concentrations in ARD. Elemental analysis methods include inductively-coupled plasma (ICP), atomic absorption spectroscopy (AAS), and X-ray fluorescence (XRF).

Static Testing

Two basic types of tests are available for determination of ARD potential: 1) ABA determines the net acid potential or net acid consuming capacity through independent measurements of maximum potential acidity (AP) and acid neutralizing capacity (NP), and 2) the NAG procedure, which yields a pH that is indicative of the likelihood of net acid generation and the amount of acid generated in the test (*e.g.,* Stewart *et al*., 2006).

ABA test results are used to calculate the net potential ratio (NPR) and net neutralization potential (NNP):

NPR = NP/AP
NNP = NP – AP ($TCaCO_3/kT$)

Table 4.7.4 in Section 4.7.1 of the ESIA shows screening guidelines for ARD potential. A sample is potentially net acid generating (PAG) with NPR < 1, non-PAG with NPR > 2, and uncertain with NPR ranging from 1 and 2 (INAP, 2009). PAG has been defined for NNP < -20, non-PAG for NNP > 20, and uncertain for NNP ranging from -20 to 20. Use of NNP is not recommended for characterizing ARD potential (INAP, 2009) because NNP is additive and must be greater than zero for NPR >1.

Site-specific NPR values have been developed in some countries and are law (regulatory criteria) in some states in the USA. At some Australasian sites, NPR > 3 is used as a conservative threshold between PAG and non-PAG. The State of New Mexico has a regulated NPR value of 3 for non-PAG, and an NPR threshold of 1.2 is law in Nevada.

The NAG test is used in conjunction with ABA to classify the acid generating potential of a sample (Stewart *et al*., 2006). A NAG pH < 4.5 indicates the sample is PAG. NPR = 1.0 separates PAG from non-PAG. A plot of NPR vs NAG pH identifies a PAG quadrant, a non-PAG quadrant, and two uncertain quadrants (INAP, 2009). Samples with conflicting ABA and NAG pH results plot in the uncertain quadrants. These samples require further test work. Sub-classification of PAG as low capacity and high capacity is also informative, which is based on the amount of acidity determined by titration to pH 4.5 (Miller, 1998). Also, sequential NAG tests should be performed on samples with pyritic sulfur contents greater than 0.7% to determine the total acidity due to incomplete oxidation of sulfide sulfur (resulting from peroxide decomposition effects).

ABA and NAG tests are inexpensive and should be applied to a large number of samples. The results are used for identifying samples requiring additional testing to better characterize ARD potential and may provide operational screening criteria for mine waste classification and management. ABA should always be conducted. The NAG test may be omitted for samples with very little sulfur or for samples with significant excess NP based on ABA test results.

Kinetic Testing

Laboratory kinetic tests are used to validate and interpret static test results and predict long-term weathering rates, ARD potential, and mine water chemistry. Both acid generation and metals leaching can be evaluated with kinetic testing. Various types and procedures of kinetic testing all involve subjecting samples to periodic leaching and analyzing the leachate. The test materials must be characterized before testing begins.

The two laboratory kinetic tests generally used are HC and column tests. HC tests are ASTM standardized tests (ASTM, 2007) conducted under fully oxygenated conditions with periodic flushing of reaction products. Information derived from the tests includes weathering rates of sulfides and dissolution rates of readily soluble primary and secondary minerals. A common endpoint for HC tests is demonstrated time-constant values of leachate parameters.

Standards do not exist for column tests, which can simulate a variety of conditions. Column tests permit precipitation of secondary minerals from constituents leached from primary minerals, providing a better assessment of drainage chemistry. Column tests may simulate site-specific conditions and mitigation measures such as covers and amended mine wastes.

Leach and Effluent Tests

The SPLP is one of several short-term leach tests that measure readily soluble constituents in mine wastes (*e.g.,* Maest et al., 2005). The test simulates the effects of short-term interaction of materials with rain and snowmelt, but it provides no information on long-term leach rates.

The effluent from NAG testing can be analyzed to provide an assessment of the effects of long-term weathering on mine water chemistry. Karlsson and Kauppila (2016) found that analysis of NAG leachate provides a reasonable estimate of metals concentrations for pH < 4 and that the NAG leachate at least indicates elements that are likely to be elevated at higher pH.

Field methods may be used to most realistically evaluate the potential for ARD and metals leaching. The methods range from rock wall washing to test piles of large quantities of materials (INAP, 2009). The advantages of field methods are assessment under ambient site conditions, including seasonal effects, and evaluation of the effects of discrete events such as intense storms or snowmelt. Monitoring leachate water quality related to historic mining activities (*e.g.,* waste rock piles and adits) can provide using information about weathering rates and water quality under ambient conditions.

2.1.1.2.3.2 Assessment of the ESIA Characterization of ARD Potential

The distributions of sample locations for ARD assessment are reasonable for both pit areas. However, the sample categories of VC and LV reveal little about specific mineralogic and rock characteristics of each sample. There are significant variations in each category.

Within the two basic rock types (VC and LV), alteration sub-types may include silica VC, silica-alunite VC, argillic LV, argillic-alunite LV, silica-sericite-clay LV, phyllic LV, and other rock sub-types, including unaltered LV. Ore may be considered a sub-type primarily of VC. Ore occurrences include hematite and gossanous hydraulic breccias and veins in faults and fractures. Colluvium is a waste type derived from VC and LV with variable grain size and composition that also requires characterization. Multiple representative samples of each rock sub-type, ore occurrence, and sediment in each of the various pit areas require characterization. Spent ore characterization should include breccia and vein types. Mineralogical analyses of each rock sub-type, ore occurrence, and sediment may reveal additional or fewer divisions based on distinct mineral assemblages, including secondary minerals, with the ultimate objective of defining geochemical test units (Maest *et al*., 2005).

Mineralogical analyses were performed by XRD and transmitted and reflected light microscopy on 8 samples of Tigranes/Artavazdes and 12 samples from the Erato pit areas (Appendix 8.1.9). Only 5 LV and 3 VC samples were analyzed from the Tigranes/Artavazdes pit area, and only 5 LV, 4 VC, and 3 colluvium samples from the Erato pit area. The number of samples is insufficient for each category, and the choice of samples was not based on sub-types of VC and LV. There is no way to know whether all rock sub-types are represented for VC and LV or whether the set of mineralogic analyses for each category is representative of the range geochemical variability and whether a mineralogic analysis is representative of any particular rock sub-type. The lack of correlation between rock sub-types and mineralogic data has repercussions for all other testing.

Based on existing mineralogical analyses, the important minerals include quartz, feldspars, sericite, illite, kaolinite, alunite, jarosite, pyrite, hematite, limonite, and goethite. Tables 4.6.2 and 4.6.3 of the ESIA and Table 9 of Appendix 8.19 (GRE, 2017), summarizing the mineralogic data for VC and LV, reveal significant variations in the mineralogy of the samples in each category which demonstrate the need for rock sub-types. Mineralogic analyses were not performed on the ore, but even composites of the ore reveal significant differences in whole rock analyses (ESIA Table 4.6.1) indicative of mineralogic differences. No mineralogic analyses were performed on colluvium in the Tigranes/Artavazdes pit area and no analyses were performed on borrow materials.

A significant number of whole rock analyses were performed for barren rock in each pit area (Appendix 4.6.2 Table 4-1), but the vast majority of analyses were just total metals. Based on Appendix 4.6.2 Table B-4, the only major element analyses that were performed are for the Tigranes/Artavazdes pit area, where only 6 analyses were performed for LV and 3 for VC. There are no analyses of Tigranes/Artavazdes spent ore. Unfortunately, none of the results can be related to rock sub-types with characteristic mineralogy and, and the results cannot be used to assess whether one particular sub-type suggests greater risk than another, which would be useful in selecting samples for other tests.

For the barren rock in the Tigranes/Artavazdes pit area, 154 ABA tests were performed without any NAG pH tests to complete the classification. Likewise, for the spent ore of this pit area, 6 ABA tests were conducted without complementary NAG pH tests. For the barren rock of the Erato pit area, 80 ABA tests were performed and only 50 NAG pH tests. State-of-the-art ARD characterization requires both ABA and NAG pH tests to classify the samples (It is noted that a plot of NPR vs. NAG pH for samples with both tests is included in Appendix 4.6.2), unless the samples have very little sulfur, or the ABA results indicate significant excess NP. The rocks have very little NP, and significant excess AP in the LV. At a minimum, all LV samples should have had the NAG pH test performed. Justification for omitting this test for the VC samples based on the amount of sulfur would be appropriate. Titration is a standard part of the NAG pH test (Stewart *et al*., 2006), and the data on the amount of acidity should have been used to further classify the sample, with sequential NAG tests for the many samples with pyritic sulfur contents greater than 0.7% (Appendix 4.6.2 Tables A-1 and A-2). None of the existing static test results can be related to rock sub-types with a characteristic mineral assemblage for interpretation of test results.

Noteworthy is that the Modified Sobek method was used for the Project ABA, which determines AP based only on sulfide sulfur. This approach is clearly incorrect for the Project because nearly all samples from both pit areas have acidic paste pH values (Appendix 4.6.2 Tables A-1 and A-2), indicative of acidic sulfate salts (e.g., alunite and jarosite), identified in both VC and LV. The analyzed percentage of sulfate should have been included in the AP calculation (INAP, 2009), which would have resulted in lower NPR values. Negative values of NPR (impossible) and units of $TCaCO_3$/kt (NPR is a unitless ratio) are reported in Tables A-1 and A-2.

HC tests were performed on only 8 barren rock samples from the Tigranes/Artavazdes pit area. No HC tests were performed for the Erato pit area. This data set is inadequate to cover the range of rock sub-types with uncertain status based on static test characterization, especially with incorrectly calculated AP and the potential for some VC rocks to be acid generating (see below). None of the HC test results can be related to rock sub-types with a characteristic mineral assemblage for interpretation of test results.

The main concern with the SPLP testing is whether the range of rocks with secondary minerals were tested without defined geochemical test units. Similarly, NAG effluent results cannot be correlated with characteristic mineral assemblages for interpretation of results. Noteworthy is the lack of NAG effluent testing for Tigranes/Artavazdes spent ore.

Section 4.6.5 of the ESIA states that the VC is not acid generating. Appendix 4.6.2 Tables A-1 and A-2 show that there are many VC samples with significant pyritic sulfur, more than double the cited “low total sulfide (around 0.15%)”, ranging to more than 5% in the extreme in both pit areas. Although these samples are a minority among the VC samples, the higher sulfide percentages provide more evidence that the VC is not homogeneous and should be sub-divided into distinct rock sub-types (geochemical test units).

Section 4.7.5 of the ESIA suggests that the HC tests would be conducted for up to a year. Four of the tests were terminated at 20 weeks. VC samples ARD-78C and ARD-80C appear to have not been given sufficient time to determine final pH based on the plots of other samples with longer test periods. The other two 20-week tests attained low and stable pH, but other parameters were not stable, including acidity, conductivity, sulfate, iron, and aluminum.

It cannot be concluded that the ARD potential of the VC does not translate into ARD generation. Two of the HC tests on VC were terminated prematurely. The three tested samples have low pyritic sulfur percentages (<0.01, 0.06, and 0.08). There are VC rocks with much higher percentages of sulfide that were not tested.

The three LV HC samples that generated no significant sulfate or iron have low pyritic sulfur percentages (0.2, 0.3, and 0.8). The other two LV samples that generated pH below 3 and high iron and sulfate have pyritic sulfur percentages of 2.1 and 4.2 percent. Many (29) LV samples (24%) in Appendix 4.6.2 Tables A-1 and A-2 have more than 2% pyritic sulfur, and 39 of 121 LV samples (32%) have significant pyritic sulfur (>0.7%). Therefore, the insignificant solute concentrations of the three LV samples must not be emphasized (as implied in Section 4.7.7 of the ESIA). Furthermore, based on the interpreted role of ferric iron in oxidation of pyrite in sample ARD-74C, the 24 % of LV with more than 2% pyritic sulfur may be expected to behave similarly.

Section 4.7.10 of the ESIA states that three of the five LV kinetic cells showed strong resistance to pyrite oxidation by ferric iron and that these samples produced consistently mild pH (greater than 4.5) with low sulfate and iron concentrations despite long-duration testing. These three samples have the low pyritic sulfur percentages (0.2, 0.3, and 0.8), which could not produce enough acidity to drive the pH below 3.5, where significant dissolved ferric iron concentrations greatly increase the rate of sulfide oxidation (INAP, 2009).

The leachate from the Site 27 Soviet era waste pile has a pH of 3.3 and high acidity. These data are a reasonable indicator of the potential of the ARD from the Amulsar Mine.

GRE initiated an on-site bucket kinetic testing program in 2017 (GRE, 2018a). The program included seventeen buckets filled with LV rock and three buckets filled with VC rock. The buckets are filled to 20-liter capacity and exposed to natural conditions. The LV sample selection was skewed toward samples with expected acidic properties. The range of pyritic sulfur of the LV samples is 0.04% to 9.48% (5 samples with <0.1% and 11 samples with >4.0%). Pyritic sulfur for the VC ranges from 0.07% to 0.13%.

GRE (2018a) stresses the bias in testing high pyritic sulfur samples. According to GRE, the ARD block model shows that only approximately 15% of LV is high AP waste. Minor high pyritic sulfide VC types were not subjected to bucket testing.

The rock was obtained from old core boxes with drilling dates generally ranging from 2010 – 2012 and one box with 2007 core. Pictures of the buckets reveal cobble-size material. ABA analyses were obtained for all test samples. ABA analyses were also performed on an additional 21 samples considered waste rock (8 VC and 13 LV).

ARD suppression tests are also being performed on high pyritic sulfur samples to determine the best amendment. In June 2018, six of the 20 bucket tests were converted to suppression tests.

The bucket testing was initiated October 2017 (GRE, 2018a). Noteworthy is the application of an initial rinse in November 2017 without leachate collection. The first leachate collection occurred December 2017 followed by four collections in May and June 2018 (date of memo is July 2, 2018). Field parameter measurements are pH, oxidation-reduction potential, conductivity, and dissolved oxygen. The December 2017 measurements show low pH (< 3.5) in 11 of the LV samples, with conductivities (μS/cm) ranging from over 1,000 to +/- 10,000. The pH of the other LV samples ranges from 4.5 to 6.0 (variable for each sample). One of the VC samples attained a pH as low as 4.0 in May 2018, and the other two VC samples generally show pH ranges from 4.5 to 6.0 (variable for each sample). Conductivities of the VC and many of the LV were in the range of 100.

A generally good correspondence is observed between ABA and bucket test results, with the 11 LV samples having pyritic sulfur greater than 4% producing pH less than 4. The one LV sample with 1% pyritic sulfur produced pH between 5 and 6 with a downward trend in May and June. The lower pyritic sulfur percentages produced the higher pH range of 4.5 to 6.0. The VC sample that produced pH as low as 4.0 (4.6 – 5.75 in May and June) has 0.13% pyritic sulfur. These results reinforce the need for sub-types of rocks (geochemical test units) and that VC has potential for acid generation even at the lower end of the pyritic sulfur range (0.13%) identified in the original ABA testing (up to and more than 5%).

GRE (2018a) stated that due to the drilling schedule, there was no fresh rock available for testing, necessitating using old core rock. Furthermore, GRE (2018a) stated that the high AP rock had oxidized in the core boxes, the objective of determining how fast the rock generates acid was not met, and that it will be necessary to redo the experiment. The oxidation observed in the core boxes, however, provides an indication of the rapidity of acid generation (with respect to drilling dates). The ramifications of the initial rinse in November 2017, as well as parameters of the leachate, are unknown. Considerable release of stored acidity in secondary minerals is probable. Measurement results in May and June 2018 display a slow, very minor increase in pH for nine samples. Minor to moderate decrease in conductivity is also recorded. Unclear is how much additional oxidation occurred between December 2017 and May 2018 and whether the increase in pH of these samples in May and June represents continued dissolution of residual secondary minerals or continued pyrite oxidation accompanied by a decrease in exposed surface area.

The results of the entire characterization program should be viewed with caution. Although all the basic types of characterization were performed, there appears to be little planning and continuity in the approach.

Noteworthy is the recent development of the ARD block model (GRE, 2018b), which incorporates subdivision of LV based on the percentage of total sulfur. Previously, all LV was assumed to be PAG and managed the same. The model is generally based on the conservative assumption that total sulfur is a proxy for sulfide sulfur and that total sulfur greater than 2 percent is strongly acid generating (SAG). This approach improves ARD management of the LV rock but does not rectify the deficiencies in characterization described above.

The block model only subdivides the LV. All VC is still considered non-PAG rock. The conclusion that the ABA data histogram (GRE, 2018b Figure 1) "*confirms*" some LV samples were "*incorrectly logged*" as VC or that "*some VC samples have very high sulfate sulfur*" is suspect. Even if the high total sulfur is sulfate sulfur in VC rocks, which is not necessarily correct (can also be sulfides in VC), the block model excludes these samples (because they are purportedly sulfates and VC).

A coordinated effort should have been employed for the characterization, beginning with careful macro-identification of rock types based on exploration core for potential definition of geochemical test units. This step would be followed by petrographic and XRD analyses to confirm distinctive lithology, texture, mineralogy, and alteration. Geochemical characterization of the potential test units can confirm, reduce, or expand the number of geochemical test units. Volumes of each test unit are estimated, and an appropriate number of samples is determined. The samples for each geochemical test unit are then subjected to the full range of geochemical tests (except HC), with mineralogic data for each test unit. The final step of characterization is kinetic testing on a representative number of samples from each geochemical test unit, with emphasis on rocks classified as uncertain by the static testing. Mineralogy of the kinetic test samples is important.

The ARD with pH in the range of 4 – 5 cannot be dismissed. Acid contributes to the rate of chemical weathering of rock, which can accelerate physical weathering. Accelerated weathering contributes to the rate of exposure of more pyrite in all rock types at Amulsar. With enough pyrite exposed, very low pH solutions develop that mobilize metals, as observed in the HC tests.

2.1.1.2.3.3 Assessment of ARD Geochemistry

2.1.1.2.3.3.1 Geochemical Reactions

The ARD Management Plan (GRE, 2017 Section 3.9.1) states the following about ARD reactions:

> The kinetics of an ARD reaction are critical in defining the environmental impacts. Two different chemical reactions typically form ARD from the oxidation of pyrite. Equation 1 involves the oxidation of pyrite in the presence of water:
>
> $FeS_2 + 7/2O_2 + H_2O = Fe^{2+} + 2SO_4^{2-} + 2H^+$ [1] (INAP, 2009)

This reaction commonly occurs in LV material tested at the Amulsar site. However, in the kinetic cells, a second reaction dominated the ARD behavior of some cells later in the testing period. This equation involves the oxidation of pyrite by ferric iron (Fe^{3+}). This reaction is much faster and has a higher stoichiometric ratio between pyrite and acidity (listed as H+).

$FeS_2 + 14Fe^{3+} + 8H_2O = 15Fe^{2+} + 2SO_4^{2-} + 16H^+$ [2] (INAP, 2009)

Equation 2 is catalyzed by the bacteria thiobacillus ferroxidans [***sic***][4]. In subsequent sections, the changeover from ARD dominated by Equation 1 to ARD dominated by Equation 2 is referred to as: "ferric iron oxidation" because ferric iron is acting as a reactant in the oxidation of pyrite.

The statement that two reactions are responsible for acidity from pyrite (FeS_2) is incorrect. GRE (2017; Section 3.9.1) disregards the roles of ferrous iron oxidation and ferric hydroxide generation (or hydrolyzed ferric iron) as steps in the generation of acid. Based on GRE (2017), all the acid in the reaction sequence in Section 3.9.1 comes from the oxidation of sulfide to sulfate, with dissolved ferrous iron (Fe^{2+}) as a reaction product remaining in solution. The discussion in Section 3.9.1 (GRE, 2017) is based on the ARD section of GARD Guide (INAP, 2009). The GARD Guide discussion, in turn, is based on a discussion of pyrite oxidation by Stumm and Morgan (1981), wherein the reactions are presented in a different sequence:

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+ \quad (1)$$
$$Fe^{2+} + ¼\ O_2 + H^+ \rightarrow Fe^{3+} + ½\ H_2O \quad (2)$$
$$Fe^{3+} + 3\ H_2O \rightarrow Fe(OH)_3 + 3\ H^+ \quad (3)$$
$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+ \quad (4)$$

Reactions 1 and 2 to 3 above are the primary contributors to acidity in pyrite oxidation. The GARD Guide reverses the order in which the reactions are presented, so that the ferrous iron oxidation is presented as Reaction 3, which is simply stylistic. However, GRE (2017) leaves out the ferrous iron oxidation reaction altogether, and in doing so leaves out half of the acid generating reactions in ARD. This significant oversight brings into question Lydian's assessment of acid generating potential of the rock and of the water quality in the ARD.

The oxidation of pyrite by ferric iron, Reaction 4 in the Stumm and Morgan (1981) sequence, only occurs after pyrite oxidation has been well established and significant acidity generated, because the ferric iron involved in Reaction 4 is only soluble and available under low pH conditions. The reaction between ferric iron and pyrite is much faster than the reaction between pyrite and oxygen and Reaction 4 will dominate if there is much dissolved ferric iron. Williamson *et al.* (2006) suggest that the reaction between ferric iron and pyrite dominates at a pH below about 3.2, with oxygen being the dominant reactant with pyrite above that pH level. The GARD Guide (INAP 2009 Figure 2-16) indicates Reaction 4 occurs at pH levels below approximately 3.2. The first three reactions in the Stumm and Morgan (1981) sequence are the primary acid-generating reactions. Because the dissolved ferric iron in Reaction 4 is a result of pyrite oxidation in the first place, the reaction does not generate any more acid per mole of pyrite than do the first three reactions. Note that once formed, ferric iron can generate acid either from hydrolysis and precipitation as hydrous ferric oxide (Reaction 3) or by reacting with additional pyrite (Reaction 4).

[4] *Thiobacillus Ferrooxidans*

GRE (2017) places emphasis on the reaction between ferric iron and FeS_2 ("*ferric iron oxidation*"), so it is instructive to examine Reaction 4 further. Presumably, pyrite oxidation is the original source of the dissolved iron and sulfate. The ferric iron is generated from the oxidation of the ferrous iron released by pyrite oxidation. Once ferric iron reaches a sufficient concentration in solution as the pH decreases, it will then start reacting with additional pyrite.

We can combine the reactions for the original reaction between pyrite and oxygen (Reaction 1), the reaction between ferrous iron and oxygen to generate ferric iron (Reaction 2), and the reaction between ferric iron and pyrite (Reaction 4) to generate an overall reaction for pyrite oxidation by ferric iron, as shown below:

Reaction of oxygen with pyrite and ferrous iron:

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+ \qquad (1)$$
$$Fe^{2+} + 1/4\ O_2 + H^+ \rightarrow Fe^{3+} + 1/2\ H_2O \qquad (2)$$

Combining these reactions:

$$FeS_2 + 7.5/2\ O_2 + 1/2\ H_2O \rightarrow Fe^{3+} + 2\ SO_4^{2-} + H^+$$

We need 14 Fe^{3+} to oxidize pyrite, so the equation to oxidize pyrite by Fe^{3+} becomes:

$$FeS_2 + 14(FeS_2 + 7.5/2\ O_2 + 1/2\ H_2O) + 8\ H_2O \rightarrow 14(Fe^{2+} + 2SO_4^{2-} + H^+) + (Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+)$$
$$15\ FeS_2 + 52.5\ O_2 + 15\ H_2O \rightarrow 15\ Fe^{2+} + 30\ SO_4^{2-} + 30\ H^+$$

Simplifying, gives:

$$FeS_2 + 3.5\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_4^{2-} + 2\ H^+$$

This combined equation is identical to Reaction 1. Therefore, the overall reaction between pyrite and ferric iron is the same as the reaction between pyrite and oxygen. The reaction with ferric iron is faster, with the ferric iron acting as a catalyst, but the overall stoichiometry is the same. The original oxidant is oxygen. The sulfate to ferrous iron ratio is 2:1 at the end of the reaction. The predominance of one reaction over another reaction cannot be determined from the final concentrations of iron and sulfate or the final pH.

Both the iron and sulfur in pyrite contribute to acidity. The sulfur contributes in the first step of pyrite oxidation (Reaction 1). However, once sulfur is oxidized and sulfate is generated, sulfur does not contribute further to acidity. Ferrous iron contributes acidity as it oxidizes to ferric iron and then hydrolyzes[5] or precipitates as ferric hydroxide[6]. Whereas acidity from sulfide oxidation is generated directly (Reaction 1), the acidity from ferrous iron is generated after iron is oxidized.

The reaction between pyrite and ferric iron (Reaction 4 in Stumm and Morgan (1981)) is abiotic. Reaction 2 (ferrous iron oxidation) is slow at acidic pH values, but it can be catalyzed by

[5] $Fe^{3+} + H_2O \rightarrow Fe(OH)^{2+} + H^+$
[6] $Fe^{3+} + 3H_2O \rightarrow Fe(OH)_3 + 3H^+$

bacteria[7]. Both Reactions 1 and 2 are slow when abiotic, so the bacteria-catalyzed oxidation greatly enhances the rate at which ARD occurs.

The ferrous iron can be transported in the ARD-impacted water until the water is oxygenated and the iron is oxidized. These processes can occur at some distance from the location of pyrite oxidization (*e.g.,* where groundwater with ferrous iron in solution discharges to a stream).

Ferric iron can precipitate as hydrous ferric oxide and generate acid, as shown by Reaction 3. Ferric iron can also precipitate as transient ferric hydroxy sulfates such as jarosite ($KFe_3(OH)_6(SO_4)_2$) or schwertmannite ($Fe_8O_8(OH)_6(SO_4)$) that make up part of the "yellow boy" characteristic of ARD. These minerals serve as stable reservoirs of stored acidity (Madden *et al.*, 2012; Stahl, *et al.*, 1993; Welch *et al.,* 2008) at low pH. At pH values above about 3 (jarosite) to 4 (schwertmannite), these minerals dissolve incongruently to hydrous ferric oxides, sulfate, and acid. Jarosite has been identified in the rocks at the site. The reaction for dissolution of jarosite is shown below:

$$KFe_3(OH)_8(SO_4)_{2)} + 3H_2O \rightarrow K^+ + 3\ Fe(OH)_3 + 2\ SO^{2-} + 3H^+$$

In this incongruent dissolution reaction, the iron remains in the mineral (solid) phase and potassium, sulfate, and acid are released to solution. Thus, after the products of the initial pyrite oxidation have been transported away in surface water or groundwater and precipitated as secondary minerals, water chemistry may be influenced by jarosite or schwertmannite dissolution, with little iron in the water (Smith *et al.,* 2005).

Aluminum minerals in soil or rock can neutralize the acid from pyrite oxidation, yielding dissolved aluminum (Al^{3+}), which behaves as a less acidic version of ferric iron. The dissolved aluminum can precipitate as secondary minerals such as alunite ($KAl_3(OH)_6(SO_4)_2$), which is also found at the Site as part of the hydrothermal alteration mineral assemblage. Aluminum precipitates as a hydroxide at a higher pH than ferric iron (Snoeyink and Jenkins, 1980) generating acid, but the pH is buffered at a higher value than the reaction for precipitation of hydrous ferric oxide. Like jarosite, alunite is stable in acidic environments and dissolves incongruently to produce gibbsite at pH above about 4.5 (Reuss and Johnson, 1986).

The iron minerals jarosite and schwertmannite are associated with acidic, iron-rich environments such as ARD and are not stable in neutral environments. These minerals are transient phases that precipitate as a result of pyrite oxidation. The widespread occurrence of jarosite in the rocks at the Site indicates that pyrite oxidation has been occurring without mining activities and highlights the potential for much greater ARD generation after mining. GRE (2017) does not discuss the contribution of jarosite to ARD.

The GRE (2017) discussion of pyrite oxidation neglects half of the acid-generating reactions (Reactions 2 and 3) and thereby underestimates the potential ARD loading of the waters at the Site (for pH > 3.2) and the treatment needed to mitigate the corresponding impacts. The ARD mitigation and treatment plan presented in GRE (2017) may prove insufficient to treat the ARD. The ferrous iron oxidation is an important process to consider because additional acidity can be

[7] Bacteria *Thiobacillus ferrooxidans*, referenced in GRE (2017), can oxidize either sulfide or ferrous iron, and may be involved in either the initial oxidation of pyrite or of the ferrous iron generated form the dissolution of pyrite.

generated at some distance from the location of the pyrite oxidation. For example, acidity in the form of ferrous iron generated by pyrite oxidation in the BRSF can be carried downstream to the equalization pond in the passive treatment system (PTS) for the Site contact water. Knowing how much ferrous iron will be entering the pond is important for estimating how much acid will be generated and need to be neutralized. In addition, the ferrous iron oxidation generates solids (ferric hydroxide, jarosite, and schwertmannite), which can coat the conveyance structures (as "yellow boy") and clog filters. A major risk for implementing PTS during operations is not knowing in advance the ferrous iron load in the water entering the system.

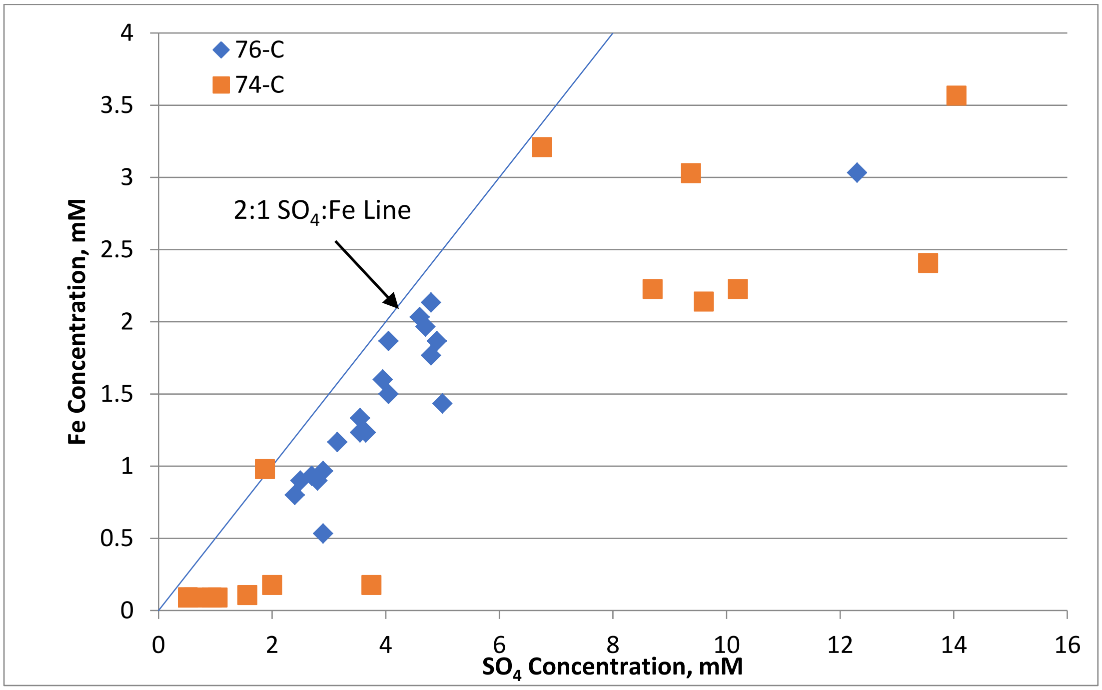
2.1.1.2.3.3.2 "Ferric Iron Oxidation"

GRE (2017) uses the term "*ferric iron oxidation*" for Reaction 4 in Stumm and Morgan (1981), in which pyrite is oxidized by ferric iron, and posits that the humidity cell (HC) test results for sample ARD-74C exhibit the effects of Reaction 4, as stated below (page 24):

> ARD-74C is the most useful sample in the sample dataset. For the first 12 weeks of the test, the cell oxidizes under oxygenated conditions using Equation 1.
>
> After 12 weeks, ferric iron oxidation begins and the rinsate has reduced pH, increased sulfate concentrations, and increased iron concentrations. This sample demonstrates that Amulsar ARD, even under ideal conditions, has resistance to ARD. As a result, this sample was utilized in subsequent geochemical modeling to define reaction kinetics (GRE, 2014d).

The HC results for sample ARD-74C show a dramatic increase in ARD generation after 12 weeks, with the iron concentration increasing by an order of magnitude and pH decreasing by 0.5 units to less than 3. The GRE (2017) interpretation does not provide an explanation for the source of ferric iron to oxidize the pyrite. Furthermore, the HC ARD-74C behavior is not simply the result of ferric iron oxidation of pyrite. At week 12, the iron concentration is around 5 mg/L, or approximately 0.1 mM. If the iron is ferric iron and reacts with pyrite according to Reaction 4, 0.007 mM of pyrite (1 mole pyrite/14 moles Fe^{3+} x 0.1 mM) will be oxidized, and the iron concentration will increase from 0.10 mM to 0.107 mM ferrous iron. Instead, the iron concentration increases to around 55 mg/L, or approximately 1.0 mM. This significant increase in iron concentration would require a bacterial population to oxidize ferrous iron to ferric iron and a low pH to keep the ferric iron in solution. The rate of pyrite oxidization would be dependent on sufficient populations of the right bacteria. There is no "*resistance to ARD*". The predominance of one reaction over another reaction cannot be determined from the final concentrations of iron and sulfate or the final pH.

If ferric iron from Reaction 2 is precipitated as ferric hydroxide in Reaction 3, rather than oxidizing pyrite, then the sulfate to iron ratio increases because the dissolved iron concentration decreases. A plot of the concentrations of iron and sulfate for HC 74-C and 76-C (Figure 2.1.1 below) shows that the iron concentrations are slightly below the expected 2:1 line (Reaction 1 or 4) at low concentrations and significantly below the line at the high concentrations.



(Source: GRE, 2014d)

Figure 2.1.1: Comparison of sulfate and iron concentrations for Humidity Cells 74-C and 76-C

Figure 2.1.1 suggests the sample ARD-74C leaching patterns for sulfate and iron reflect the characteristic initially slow pyrite oxidation, with some of the iron precipitating as hydrous ferric oxide. This behavior is particularly evident from the HC leachate analyses at the higher sulfate concentrations (large sulfate/iron ratios).

GRE (2017, page 26) further posits that there is some "*suppression agent*" that is inhibiting the reaction between ferric iron and pyrite, as stated below:

> As a result, the material shows that the LV rock has some natural suppression agent that prevents the formation of ferric iron oxidation. The suppression could be any or all of the below:
>
> - Thiobacillius Ferroxoidants [***sic***][8] have a much slower sulfide reaction rate in cold climates (Sartz, 2011);
> - The argillic texture (with approximately 10% clay content) inhibits the flow of oxygen within the pile, and therefore, oxidation; and/or
> - The LV mineral has some residual natural resistance to ferric iron oxidation that is only overcome in the extraordinary conditions of a long-term humidity cell test.
>
> This natural resistance is a critical conclusion of the characterization of Amulsar mine waste.

The GRE (2017) assessment is misleading. The rate of pyrite oxidation is limited when the bacterial population is low and the pH is too high for ferric iron to be to be soluble.

[8] *Thiobacillus ferrooxidans.*

2.1.1.2.3.3.3 Summary of ARD Geochemistry Assessment

GRE (2017) assessment of ARD reactions that would occur in the Amulsar rocks is misleading because the analysis:

1. Fails to recognize the importance of ferrous iron oxidation in the ARD reaction sequence in generating acid and precipitating mineral phases (solids).
2. Postulates that the reaction of pyrite by ferric iron has a higher stoichiometric ratio between pyrite and acidity. The overall reaction between pyrite and ferric iron is the same as the reaction between pyrite and oxygen. The reaction with ferric iron is faster, with the ferric iron acting as a catalyst, but the overall stoichiometry is the same. The ferric iron oxidation is just one of the two pathways for pyrite to be oxidized, and the two pathways cannot be distinguished based on the products generated.
3. Postulates that there is some "*natural suppression agent*" inhibiting the oxidation of pyrite by ferric iron in the LV ores, but the rate of pyrite oxidation is limited when the bacterial population is low and the pH is too high for ferric iron to be to be soluble.
4. Underestimates the potential for ARD generation and the associated water quality, environmental impacts, and water treatment requirements.

The importance of the above assessment of ARD generation on the input water quality to the proposed PTS from the BRSF is discussed in Section 2.1.5.

2.1.1.3 Seismic Hazard Potential

2.1.1.3.1 Tectonic Setting

Section 4.6.1 of the ESIA conveys the tectonic setting. The Project Area is located in the Lesser Caucasus Mountains, which resulted from subduction and closure of the Neo-Tethyan Ocean (Adamia *et al.,* 2011; Grosjean *et al.,* 2018). The northeastern shore of Lake Sevan is adjacent to the suture zone (Figure 4.6.1) and outcrops of the Sevan-Akera ophiolites (Adamia et al., 2011).

2.1.1.3.2 Seismicity

Section 4.6.1 of the ESIA states that the Project Area is NOT located within the major zones of tectonic activity in Armenia, but that the area is geologically active based on the occurrence of young basalt scoria cones. On the other hand, Section 4.6.4 of the ESIA states that "*the Project licence is located within a seismically active region of the Arabia-Eurasia plate boundary zone*" and "*that there are 17 fault zones with a total of 53 fault segments within approximately 250 km of the project site*". Adamia *et al.* (2011) state that the recent geodynamics of the Caucasus and adjacent territories are determined by their position between the still converging Eurasian and Africa-Arabian plates. Furthermore, according to geodetic data, the rate of the convergence is approximately 20‑30 mm/yr, of which about 2/3 is likely to be accommodated south of the Lesser Caucasus (Sevan-Akera) ophiolitic suture, mainly in south Armenia, Nakhchevan, northwest Iran, and Eastern Turkey.

Section 4.6.4 of the ESIA indicates that historical records document the occurrence of 107 strongly-felt earthquakes in the Republic of Armenia (RA) from 600 B.C. to 2003. Armenian records indicate that the Site has experienced strong to very strong shaking at least three times in the last 900 years (Golder, 2013). Figure 4.6.8 (Section 4.6.4 of the ESIA) shows that the Project Area is surrounded by the epicenters of the historic earthquakes and “fault seismic sources”.

Two large, devastating earthquakes occurred in the Caucasus in the last 20 to 25 years (Adamia *et al.,* 2011). The first one was the magnitude 6.9 Spitak Earthquake on December 7, 1988, whose epicenter was located within the Lesser Caucasus-Northern Armenia near the Georgian border. The epicenter of the Spitak earthquake was related to the regional Pambak-Sevan fault, constituting a branch of the Sevan-Akera ophiolite suture. Another large seismic event was the magnitude 7.2 Racha earthquake on April 29, 1991. This earthquake was located in Central Georgia in the southern foothills of the Great Caucasus.

Section 4.6.4 of the ESIA indicates that the Pambak-Sevan-Sunik Fault Segment 4 (PSSF4) is located approximately 10 km north of the Project Area (Figure 4.6.8), and that it has an average horizontal slip rate of 1.55 mm/yr (Golder, 2013). Golder’s research indicates that the estimated maximum magnitude earthquake from the PSSF4 would be M 7.2 (M is the moment magnitude scale, which is the equivalent of the Richter Magnitude Scale). Golder (2013) states that the PSSF4 is not known to have generated a major earthquake in historic time (approximately the last 10,000 years).

Figure 4.6.8 shows two other active or potentially active faults within 15 to 20 km of the Project Area (PSSF5a and GF5). The estimated maximum magnitude earthquake for the Pambak-Sevan-Sunik Fault Segment 5a (PSSF5a) is M 6.9, with an average horizontal slip rate of 1.3 mm/yr. Golder (2013) assigned an estimated maximum magnitude earthquake of M 7.1 to the Garni Fault Segment 5 (GF5) and an average horizontal slip rate of 1-2 mm/yr. Noteworthy on Figure 2 of Golder (2013) is the location of a 5.0 – 5.9 epicenter 25 - 30 km of the Project Area.

The foregoing text underscores the seismic hazard risk for the Project Area. The historical record of pre-instrumental and instrumental earthquakes indicates that strong to very strong earthquake shaking has probably occurred at the Project Area at least three times in the last 900 years (Golder, 2013). Golder’s seismo-tectonic model defines the active and potentially active seismic sources that can contribute to earthquake ground motions in the Project Area. The PSSF4 makes a strong contribution to Project Area seismic hazard because the PSSF fault system is the longest active structure in the RA with the greatest slip rates and strongest earthquakes (Golder, 2013).

Golder’s assessment of seismic hazards is generally thorough (see below for further assessment) and conservative. Key mining infrastructure sites that require earthquake ground shaking estimates and seismic design parameters are the HLF, BRSF, open pits, crushing plant, and overland conveyor system. However, it is noteworthy that the recommended seismic parameters are based on ASCE 7-05. The ASCE 7 standard *Minimum Design Loads for Buildings and Other Structures* is the document that the *International Building Code* (IBC) relies on for its structural provisions (Ghosh, 2014). ASCE 7-05 has been replaced by ASCE 7-10 in the 2012 IBC. Major revisions in the ASCE 7 standard include seismic design provision.

2.1.1.3.3 Assessment of Active Faults in the Project Area

Section 4.6.4 of the ESIA states that Golder’s field investigations and review of available literature and satellite imagery found no geomorphic evidence for traces of faults or other tectonic geomorphology within the Project Area, including the proposed sites of the BRSF, HLF, crushing plant, and open pits, and that there is a very low potential for surface fault rupture within the Project Area.

Section 2.1.1.2.2.2.1 of this report makes it clear that there are major faults within the Project Area, including the vicinity of the mine pits and beneath the BRSF. The bounding rivers are expressions of major faults, including potentially the Vorotan River, which may reflect the occurrence of PSSF5a adjacent to the Project Area (Golder, 2013 Figure 2). The PSSF fault system is active. Assuming the southeast course of the reach of the Vorotan River adjacent to much of the Project Area is an expression of PSSF5a, several sharp bends in the Vorotan River southeast of the Project Area are strikingly similar in their northeast orientation (Appendix A), which is consistent with antithetic strike-slip faults associated with dextral displacement of PSSF5a. It is also reasonable to consider that seismicity associated with PSSF5a could result in movement along the other major faults in the Project area, including the Zirak Fault under the BRSF and the Agarakadzor Fault passing through the pit areas.

Only a small, insufficient portion of the satellite image that was provided could be viewed. However, based on the trace of the Agarakadzor Fault on the Geological Map of Vayots Dzor, alternate interpretations of its trajectory or fault splays northeast from the Darb River are indicated on a topographic map and a physiographic map showing the Agarakadzor Fault (Appendix A). The alternate interpretations suggest that the fault and/or the splays pass beneath or near the BRSF. Two notable features on both maps are the large northeast bend in the Vorotan River and the gorge with a tributary of the Darb River. These lineations may be expressions of the fault.

2.1.1.4 Groundwater Flow

Baseline groundwater is summarized in Section 4.8 of the ESIA. The Groundwater Study Area (GSA) was defined as the area within the hydraulic boundaries formed primarily by the Arpa, Darb, and Vorotan Rivers (EISA Section 6.9, Figure 6.9.1[9]). The perimeter of the GSA passes through Kechut Reservoir in the northwest and Spandaryan Reservoir in the southeast. The GSA is appropriately defined. The structural control of the boundary-rivers ensures that flow and transport from the GSA do not traverse these boundaries.

The villages of Kechut, Gndevaz, Saravan, Saralanj, Gorayk, and Ughedzor are located within or immediately adjacent to the GSA. Jermuk is located to the north along the Arpa River, outside this hydraulically-defined GSA. The Jermuk Geothermal Park is north of the Arpa River.

Areas of focused hydrogeological and geotechnical investigations include the sites and vicinities of the proposed mine facilities (the open pit areas, BRSF, and HLF). An area northeast of the HLF and an area southeast of Amulsar Mountain on the east bank of the Vorotan River were also investigated at multiple locations.

2.1.1.4.1 Hydrostratigraphy

Five hydrogeologic units were delineated in the GSA: Colluvium, silicified Upper Volcanics (VC), argillically-altered Lower Volcanic Andesite (LVA), unaltered Lower Volcanics (LV), and Cenozoic Basalt Flows. Brief descriptions are provided:

[9] For clarity, Figure 6.9.1 should have been included in Section 4.8 of the ESIA.

Colluvium

Colluvium overlies bedrock throughout much of the GSA, with thickness ranging from less than 1 m up to 20 m. The characteristics of the colluvium are variable. Descriptions range from cobbles with some silt and clay to silty clay with little gravel or cobbles. Permeability is variable. The colluvium is locally saturated in the GSA. In the drainages at lower elevations, silty clay colluvium restricts downward migration of groundwater, generating perched conditions (*e.g.,* in the drainage northeast of the HLF). Fine-grained colluvium locally restricts discharge of groundwater (*e.g.,* in the drainage east of the BRSF), where monitoring wells have water levels above ground surface.

Upper Volcanics (VC)

The silicified VC crop out along the Amulsar Mountain ridge and on its eastern flank and extend to a depth of over 300 m below Amulsar Mountain, with interleaved panels of LVA. Faults and low permeability stratiform panels of LVA compartmentalize perched and seasonal groundwater in the VC. Continuously saturated VC occurs at deeper levels. Permeability is fracture controlled.

Argillically-Altered Lower Volcanic Andesite (LVA)

The argillically-altered LVA occurs within the VC as stratiform interleaved panels and beneath the VC. LVA crops out on the west side and north end of the Amulsar Mountain ridge. The depth of the argillic alteration is unknown. The lateral extent of the halo of argillic (and phyllic) alteration limits the lower elevation of the outcrop to approximately 2,000 m above sea level (asl), where the underlying unaltered LV are exposed at ground surface.

The LVA is described as predominantly amorphous clay in the central area of the ridge. Where LVA is interleaved with VC, the LVA is believed to generate perched groundwater conditions.

Unaltered Lower Volcanics (LV)

The unaltered LV comprise a thick, sub-horizontal sequence of bedded andesite, mass flow breccias, volcanogenic conglomerate, and sedimentary rocks. These rocks crop out all around Amulsar Mountain, extending from approximately 2,000 m asl on the west side of the ridge to the gorge of the Arpa River. The LV is heterogeneous and has variable hydraulic properties, especially at the lower elevations. The andesites within the sequence have low to moderate permeability. The mass flow breccias and volcanogenic conglomerates at the base of the sequence may be highly permeable. The sedimentary rocks are typically clay-rich and have low permeability. Springs issuing from the LV are consistent with high anisotropy in hydraulic conductivity due to the interbedded nature of the sequence.

Cenozoic Basalt Flows

The Cenozoic Basalt Flows overlie the LV and intrusive rocks on plains to the east, west, and south of Amulsar Mountain, and extend northwest from the scoria cone north of the BRSF. The basalts are at least 120 m thick. Locally, the basalts are intensely fractured and permeable. Drilling encountered highly fractured zones within the basalt sequence (possibly flow tops or bottoms or scoria zones) which are interpreted to be transmissive preferential pathways.

2.1.1.4.2 Hydraulic Conductivity

Slug and packer tests were performed in areas that include the ore bodies, the HLF, and the BRSF. These data are summarized in Table 4.8.1 and Appendix 4.8.1 of the ESIA, the latter showing 58 entries of singular test values or ranges, 23 in basalt, 27 in LV, 6 in VC and 2 in colluvium. Many of these entries are for the same location. A map showing the locations of the tests across the GSA is not included in the ESIA or appendices. Therefore, the locations were circled on a map to evaluate the spatial distribution of data (Appendix B).

The number of test locations is 35 (one well in the pit area is not posted). The test locations are concentrated in the pit areas, the BRSF, and the HLF, with 4 tests in an area northeast of the HLF. The 3 tests on the east side of the Vorotan River are outside the GSA and the groundwater model domain.

No pumping tests were undertaken, which is a serious omission in the characterization of hydraulic properties. Pumping tests are a standard procedure for hydraulic characterization and are indispensable for fractured rock. Slug and packer tests provide very localized and discrete data on the hydraulic conductivity. Only long duration pumping tests can provide a good indication of the bulk hydraulic conductivity of fractured rock, which is dependent on the extent of fracturing and fracture connectivity, including bedding-plane structures. Pumping tests should have been performed in the areas of the mine facilities and pits at various depths, as well as several in each rock type across the GSA. If cross-sections had been constructed across the GSA, they may have revealed the occurrence of structures, which would be important in the planning for pumping tests. In addition to the bulk hydraulic properties, pumping tests are essential to identify and assess anisotropy and boundaries (e.g., faults and rivers/streams). Properly planned observation well locations can reveal the locations of boundaries and the extent of influence. For example, the extent of fracture connectivity to a river could be investigated.

Given the environmentally-sensitive setting, the limited distribution of hydraulic tests and the lack of pumping tests are inadequate for characterizing the hydraulic properties across the GSA. Fractured rock has heterogeneous hydraulic properties (Table 4.8.1 and Figure 4.8.8 show a range of 4 or more orders of magnitude), which are dependent on rock type and stratification (which are variable across the GSA) and proximity to structures. The rivers are structurally-controlled, and these structures may be assumed to have uniquely imparted structural fabric and fracture characteristics in their region of influence. Large areas of the GSA, from the mine pits and facilities to the rivers and reservoirs are uncharacterized and cannot be assumed to have the same hydraulic properties of the tested areas.

The water balance for the GSA, estimates of solute transport velocities, and assessment of potential impacts are dependent on good hydraulic characterization. These important objectives of the characterization work can only be attained with a well-constrained numerical groundwater model, especially for this type of geologic setting. The calculated geometric means of [local] hydraulic conductivity (Table 4.8.1 of the ESIA) and the summary of [local] hydraulic conductivity values for impact assessment (Table 4.8.2 of the ESIA) are meaningless for comparisons of rock types, unrepresentative due to the large ranges, and especially unreliable for assessments.

2.1.1.4.3 Potentiometry

Figure 4.8.13 of the ESIA is a map of contoured mean water levels across the GSA. Figure 4.8.14 in the ESIA is a contour map of water levels measured for a specific period between May 15 and June 15, 2014. Elevations of perennial springs were also used to constrain the contours.

These maps of potentiometry are similar, as expected. The shape of the flow field is broadly consistent with the control of the three major river valleys on groundwater flow and discharge. There are many tributary streams throughout the GSA, and presumably some of these streams are perennial, at least in the lower reaches. The text (Section 4.8 of the ESIA) states that it is likely that groundwater discharges to other major stream valleys to the south of the HLF and to the south of Amulsar Mountain ridge. Elsewhere, the text states that groundwater discharge occurs to streams in the BRSF area, the HLF area, and the valley east of the BRSF, and that it is unlikely these streams are isolated cases. The text further states that groundwater discharge is also likely to occur to similar streams across the GSA and to streams on the lower portions of the eastern face of Amulsar Mountain which have not been monitored or investigated.

As part of the baseline studies, all streams within the GSA should have been characterized as ephemeral or perennial, with corresponding flow rates. The contours of potentiometry should conform to groundwater discharge to all perennial streams, and groundwater flow modeling should incorporate these controls. Figure 4.8.14 of the ESIA shows a potentiometric high west of the Tigranes-Artavasdes ridge area that is inconsistent with topography and ESIA Figure 4.8.13.

These maps of potentiometry are composites of all water levels, irrespective of the depth of the well screens. Noteworthy is that downward vertical gradients are significant in this geologic setting and especially strong at the higher elevations of the ridge area. Heads measured in deep well screens can be much lower than heads in shallow wells. Section 4.8.5 of the ESIA states that all locations surrounding the Amulsar mountain ridge have strong downward vertical components of hydraulic gradient. Even at much lower elevations of the mountain, large head differences are observed between shallow and deep wells in the same location (*e.g.,* Table 4.8.10 of the ESIA). Therefore, the potentiometric maps are very general with respect to true potentiometry. Nevertheless, the general directions of lateral flow implicit in the potentiometric maps are correct.

2.1.1.4.4 Perched Groundwater

Perched groundwater is a recurrent theme in ESIA descriptions of the characterization of groundwater. Although transient perched groundwater occurs, it is less common than assumed. Transient interflow of precipitation and snowmelt could be a perched condition. However, cited examples of large head differences in shallow and deep wells are not evidence for perched groundwater. In this regard, water levels in shallow wells of the pit areas are not all necessarily indicative of perched water. Strong vertical gradients can give the appearance of perched water. Depth-separated water inflows during drilling are also not evidence of perched groundwater. The extent and connectivity of fractures intersecting the borehole account for differences in inflow in an otherwise continuously fracture-saturated section of rock.

2.1.1.4.5 Fracture Flow

Widespread fracture permeability, including bedding-plane fractures, is an important factor in groundwater flow and rates of transport throughout the GSA. The significance of this phenomenon cannot be understated. Transport of contaminated groundwater is many orders of magnitude greater in fractured media over porous media. The extent of connectivity of fractures, however, determines whether rapid flow and transport occur. Only through conducting pumping tests and groundwater tracer tests can fracture connectivity be assessed.

2.1.1.4.6 Springs

Section 4.8.5 of the ESIA indicates that comprehensive surveys of springs were conducted in November 2013 and May 2014. Included in the surveys are the Jermuk geothermal springs outside the GSA. Drawing 4.8.3 in Appendix 4.8.7 of the ESIA shows the locations of springs in the GSA. The springs were classified as Types 1, 2 and 3:

- **Type 1:** Perennial (continuous flow) geothermal springs representing groundwater discharge associated with regional-scale flow paths. Snowmelt does not influence the flow rate. These springs are located in and around Jermuk.
- **Type 2:** Perennial springs representing groundwater discharge with short- to intermediate-length flow paths. These springs are located on the flanks of Amulsar Mountain ridge and at lower elevations near the Vorotan, Arpa, and Darb Rivers. The flow rates of these springs are seasonally variable. Some of the Type 2 springs with the largest flow rates occur in the BRSF site and the adjacent valley at the north end of the Amulsar Mountain ridge and near Kechut Reservoir at the base of the Cenozoic Basalt.
- **Type 3:** Ephemeral springs (discontinuous flow) characterized by groundwater discharge associated with short flow paths, short-term flow, rapid flow velocities, and generally snowmelt. Many of these springs are located at high elevations on Amulsar Mountain. At lower elevations, the springs represent discharge of interflow from colluvial deposits and shallow weathered rock horizons.

The Type 1 springs around Jermuk are all north of the GSA and would not be impacted by the Mine. Type 2 springs include the Sevan group, which supplies the community of Gndevaz, but is well outside the GSA and would not be impacted by the Mine. Type 3 springs presumably have extremely variable flow rates, dependent on annual precipitation and snowpack, and flow measurements are unnecessary.

Type 2 springs in the northern part of the GSA include the Madikenc group, which supplies the community of Kechut. Table 4.8.11 of the ESIA shows November 2013 flow measurements for only 3 (SP80, SP 83, and SP89) of the 6 springs shown on Drawing 4.8.3 in the vicinity of Kechut. It is unclear whether all 6 springs are part of the Madikenc group. Figure 2 of Appendix 4.9.5 of the ESIA shows several other springs within the GSA in the vicinity of Kechut that apparently weren't evaluated during the survey (no assigned number). The text in Section 4.8.6 of the ESIA states that the November 2013 survey identified only a small number of flowing springs and that a further five flowing locations had no flow estimate. The latter springs are not specified. It is unclear whether the other 3 springs on Drawing 4.8.3 were flowing, as well as the other springs on Figure 2 of Appendix 4.9.5. Because springs in this area supply Kechut, this information should have been provided, and if the springs were flowing, the rates should have been measured.

Type 2 springs in the southern part of the GSA include numerous discharge locations in the vicinity of Benik Pond. The springs and pond are used by the itinerant population of Ughezdor.

The CheyratiDuz springs and the Shlak springs, which supply water for residents of Ughedzor and Saralanj, respectively, are on the south side of the Darb River, outside of the GSA, and would presumably not be impacted by the Project (unclear from available data whether the upper reaches of the Darb River above Ughezdor are perennial, a prerequisite for a groundwater boundary). The potential for impacts to the Pluskandyal springs are even less certain. The Pluskandyal springs are on the east side of the upper reach of the Darb river that flows to the north. Although these springs are also south of the defined GSA, the GSA is not bounded by a river for at least 1,000 m in the area of Vorotan Pass, and it is unclear whether the upper reaches of the Darb River and the other stream on the east side of Vorotan Pass (Porsughlu River?) flowing into Spandaryan Reservoir are perennial.

Flow was not measured at the Pluskandyal springs or the other community springs southeast of Ughezdor. Flow was also not measured at the springs around Benik Pond. The flow rates should have been measured because the springs are water supply for the local communities. Likewise, flow rates for the two springs on the south side of the Porsughlu River that supply water to Gorayk should have been measured.

Section 4.8.6 of the ESIA states that several potentially significant springs were not visited during the November 2013 survey. There were only two surveys, and the November 2013 survey is the only survey in the dry season when perennial springs are identified and characterized. Drawing 4.8.3 in Appendix 4.8.7 shows a large number of springs, especially in the vicinity of the Amulsar Mountain ridge. In general, given the importance of springs to the local communities, including shepherds and ranchers, and the potential for impacts to the springs from the mine pits, the springs flow characterization is inadequate.

2.1.1.4.7 Kechut-Spandaryan Tunnel and Mineral Exploration Adit

Two excavations in the GSA are below depths to groundwater. The most significant excavation/structure is the Kechut-Spandaryan tunnel, which is a concrete-lined structure traversing the GSA for 21 km from the Spandaryan Reservoir at the southeast extent of the GSA to the Kechut Reservoir at the northwest boundary of the GSA. The tunnel elevations at the Spandaryan Reservoir and Kechut Reservoir, respectively, are approximately 2,033 m asl and 1,998 m asl. The gate at the Spandaryan Reservoir is currently closed. Discharge at the Kechut Reservoir indicates that groundwater is entering the tunnel.

An excavation for mineral exploration (AWO30 adit) east of the BRSF extends from monitoring location AW030 (or SP13.7) with multiple branches at least 650 m to a location below the BRSF valley, where it is estimated to be 80 m below ground surface. A continuous groundwater discharge occurs from the adit.

2.1.1.4.8 Groundwater Recharge Estimate

Section 4.8.6 of the ESIA describes several approaches used to estimate recharge to groundwater. The approaches include baseflow estimates based on the increase in river flow between two spot flow measurement stations on the Vorotan and Darb Rivers during low flow periods combined with estimates of the contributing area of the watershed between the two stations. This approach indicates distributed recharge rates between 290 and 460 mm/year.

The watershed yield approach was used to estimate recharge based on continuous flow data for several stations on the major rivers and tributaries during the periods of November 2012 – May 2013 and December 2013 – May 2014. Average flows were calculated at each station for each period, unit discharges based on watershed area were determined, and unit discharges were estimated for each month based on the average unit discharges. There is no explanation given in Section 4.8.6 or Section 4.9.5 of the ESIA of how the monthly unit discharges were calculated (Tables 4.9.7 and 4.9.8 of Section 4.9.5 of the ESIA). The calculated monthly unit discharges for December, January, and February of each year were used to calculate the average monthly winter discharges for each year, which were converted to annual discharge or annual equivalent recharge. These recharge values vary widely, from 90 mm/year to 610 mm/year (Table 4.8.13).

Section 4.8.6 of the ESIA concludes that the overall calculated recharge rates from the watershed yield approach are typically between 150 mm/year and 300 mm/year. There is no basis for this statement about typical recharge rates. The average value of the recharge rates in Table 4.8.13 is 254 mm/year.

A water balance methodology (soil moisture balance) was also used to estimate recharge rates. The results are based on a lot of assumptions, including snowpack equivalent precipitation, an estimated percent sublimated, melt release time percentages, runoff estimates, and assumptions about infiltration into exposed bedrock. These results indicate approximately 100 mm/year on Amulsar Mountain and 50 mm/year in lower areas of the GSA.

The summary of Section 4.8.6 of the ESIA concludes that the soil moisture balance approach underestimates recharge, and that based on observed flows and groundwater hydrographs, recharge is considered to be between 200 mm/year and 250 mm/year across much of the GSA, with the greatest rates of infiltration occurring at the higher elevations. However, a large range in values was calculated from the various approaches. The only certain conclusion is that there is considerable uncertainty in the recharge rate. The rate is extremely variable across the GSA. Noteworthy are the recharge estimates based on flow of the major rivers, which are among the higher values of the estimates, ranging from 244 mm/year to 460 mm/year.

2.1.1.5 Surface Water Hydrology

Baseline surface water hydrology is summarized in Section 4.9 of the ESIA. The area of investigations encompasses the Vorotan River valley, the Arpa River valley, the Kechut Reservoir, and the Spandaryan Reservoir. Focused studies were performed on the watersheds of the Vorotan, Arpa, and Darb Rivers.

2.1.1.5.1 Regional Setting

Figure 4.9.1 of the ESIA shows the location of the Amulsar Project in the context of the two major rivers adjacent to the Project Area and Lake Sevan. Lake Sevan and the Kechut Reservoir are linked by a tunnel that directs flow by gravity to Lake Sevan. The Spandaryan-Kechut tunnel connects the Spandaryan Reservoir south of the Project Area with the Kechut Reservoir north of the Project Area, but surface water flow does not occur through this tunnel.

Lake Sevan is protected by Armenian law which permits no activity that may negatively impact the lake and its ecosystem. The BRSF lies within the “immediate impact zone” of Lake Sevan.

2.1.1.5.2 Watersheds

Figure 4.9.2 of the ESIA shows mine facilities with respect to the delineated watersheds of the Arpa, Vorotan, and Darb Rivers. Towns and villages are also indicated on this map. The mine pits and the BRSF are located along the surface water divide between the Vorotan and Darb watersheds. The BRSF lies wholly within the uppermost area of the Arpa watershed. The HLF, adsorption-desorption recovery (ADR) plant, passive water treatment (PWT) system, and crusher are within the Arpa watershed. Table 4.9.1 of the ESIA summarizes some general characteristics of the watersheds.

The Arpa River flows southwest from Kechut Reservoir, passing within 0.6 km of the nearest mine facility (HLF). In the vicinity of the Project Area, the Vorotan River flows generally southeast to the Spandaryan Reservoir, located approximately 6.3 km southeast of the Tigranes-Artavazdes pit. The Darb River flows westward to its confluence with the Arpa River. The Kechut Reservoir is approximately 4.5 km from the nearest mine infrastructure. The Gndevaz Reservoir, east of Gndevaz village in the Arpa River watershed, provides a source of water for livestock. The Jermuk Hydrothermal Springs are upstream of the Kechut Reservoir. Benik's Pond is a small tarn (1 ha) on the west side of Amulsar Mountain in the Darb watershed that is fed by springs and runoff.

2.1.1.5.3 Flow and Stage Monitoring

Long-term public flow data for the major rivers are limited. Historic data are only available for the Vorotan River.

The long-term flow data for the Vorotan River establish its perennial character in the vicinity of the Project Area. The maximum flow rate occurs in the spring during snowmelt. Baseflow is sustained even during dry years at very low rates.

The Vorotan-Borisovka gauge was located in the current footprint of the Spandaryan Reservoir, where it recorded Vorotan River flow from 1943 to 1987 (45 years). The gauging station was relocated to Gorayk, shown on Figure 4.9.6 of the ESIA. The Vorotan-Gorayk gauge recorded flow from 1987 to 2006.

The data for the Borisovka gauge were scaled (using flow/unit area watershed) to the smaller watershed above the Gorayk gauge to produce a data set spanning the entire period from 1943 to 2006. Percentiles of monthly discharge and monthly precipitation were calculated on an annual water year basis using the data for 1962 to 1987 (no explanation was provided for the limited period) and plotted on Figure 4.9.4 of the ESIA. This graph demonstrates that the highest precipitation rates occur in May and June during snowmelt, augmenting discharge, which attains the maximum rates during this period of the year. Discharge during May and June can be as high as 15 to 20 m^3/sec. Discharge from August through March is typically less than 5 m^3/sec.

The Arpa River is also likely naturally perennial adjacent the Project Area. However, the Arpa River reach downstream of the Kechut Reservoir is a regulated waterway, where discharge is dependent on releases from the reservoir. These data are apparently unavailable. Section 4.9.4 of the EISA suggests the hydropower plant west of Gndevaz may divert water directly from the Kechut Reservoir to the plant during low flow periods, potentially augmenting discharge in the Arpa River downstream of that location. The lack of historic flow data for the Darb River and its smaller watershed make it less certain that the river is perennial throughout the study area.

Point flow measurements were made by Lydian for the Arpa, Darb, and Vorotan Rivers and several tributaries within the study area in 2008, 2010 and 2011. Continuous flow monitoring was undertaken for these rivers from November 2012 to May 2013 and December 2013 to May 2014.

Locations of continuous and spot flow measurements are posted on Figure 4.9.5 of the ESIA. Figures 4.9.6 and 4.9.7 of the ESIA show the locations of continuous monitoring on the three main rivers and tributaries, respectively, on delineated watersheds. Table 4.9.4 of the ESIA summarizes the spot flow measurements from 2008 to 2015. Appendix 4.9.2 of the ESIA includes specific dates of the spot flow measurements.

The continuous flow monitoring stations established for the Project on the Arpa, Darb, and Vorotan Rivers are generally adequate. Given the size of the Project footprints in relation to the size of the watersheds, any potential impacts to river flow rates would be insignificant and immeasurable with respect to natural discharge variations. Also, the regulated discharge from the Kechut Reservoir would make any interpretations of impacts questionable.

A few apparent deficiencies in continuous flow monitoring are in the vicinity of Vorotan Pass. A station at the bend on the upper Darb River, where the course changes from northward to northwestward, would determine whether flow is perennial or ephemeral in that location (given the importance to groundwater flow modeling). Likewise, a station on the east side of Vorotan Pass on the upper reach of the (Porsughlu River?) flowing into Spandaryan Reservoir would serve the same purpose. A station should also be added to the stream below Benik's Pond to monitor potential effects of the Tigranes-Artavasdes pit. These locations should be incorporated into the monitoring program.

The methods to estimate flow are acceptable. Section 4.9.5 of the ESIA states that the stage dataset is presented graphically as instantaneous and daily average hydrographs in Appendix 4.9.2 and that the record of estimated flow is presented graphically in this appendix. These graphic representations of the data are missing from Appendix 4.9.2 and could not be examined.

Tables 4.9.7 and 4.9.8 of Section 4.9.5 of the ESIA present continuous flow data statistics for several stations on the major rivers and tributaries during the periods of November 2012 – May 2013 and December 2013 – May 2014. Average flows were calculated at each station for each period, unit discharges based on watershed area were determined, and unit discharges were estimated for each month based on the average unit discharges. There is no explanation given in Section 4.8.6 or Section 4.9.5 of the ESIA of how the monthly unit discharges were calculated.

The ESIA does not provide an explanation for the hiatus in continuous flow monitoring between May 2013 and December 2013. The missing time includes some months with presumably the lowest river discharge. Also, Table 4.9.5 of the ESIA reveals missing data for one or both of the continuous monitoring periods at some stations on the major rivers, with only one period of data collection for the one Vorotan station and neither period for both Darb stations. Of the four stations on the Arpa River, only one station collected data for both periods. Termination of the continuous discharge monitoring after May 2014 is questionable. The groundwater balance for the Site and the assessment of solute fate and transport are dependent on good characterization of baseflow.

The plot for the Vorotan River based on long-term public data (ESIA Figure 4.9.4) provides a good summary of the river behavior throughout the year and variations about the mean. A considerable amount of discharge data was collected for the other rivers. However, there is no synthesis of the data (using the spot and continuous measurements) and corresponding graphical representation of the flow characteristics and variations throughout the year for the Arpa and Darb Rivers.

2.1.1.5.4 Flood Risk

Flood risk is extremely low. The Mine facility closest to a river spatially and in elevation is the HLF. The HLF is at least 200 m above the Arpa River. The Arpa River is a managed watercourse, with mitigation of flood provided by the Kechut Reservoir. All other mine facilities are much further from and higher above the rivers.

2.1.1.6 Surface Water and Groundwater Composition and Quality

Sections 4.8.7, 4.8.9, and 4.9.6 of the ESIA present results of groundwater and surface water composition, quality, and isotopic characterization for the GSA and Jermuk. The characterization was supplemented recently with additional ion and isotopic data (Golder, 2019). Sampling localities include Amulsar Mountain spring waters, Jermuk geothermal springs, the Spandaryan Reservoir, Spandaryan-Kechut tunnel outfall, the Kechut Reservoir, the Gndevaz Reservoir, adits, groundwater wells across the GSA, and numerous locations on the Arpa, Vorotan, and Darb Rivers and tributaries.

2.1.1.6.1 Major Ion and Isotopic Characteristics

Appendix 4.8.4 of the ESIA and Golder (2019) present the results of major ion characteristics on Piper and Durov plots. The most important feature of these plots is a set of points representing Jermuk samples that is completely distinct from all other sampling locations (ESIA Appendix 4.8.4 Figures 1 and 2; Golder, 2019 Figures 1 and 2). Furthermore, the majority of Jermuk samples have distinctly higher conductivity than GSA samples (ESIA Appendix 4.8.4 Figure 11).

One 2013 Jermuk sample location (DWJ4) has some major ion characteristics (ESIA Appendix 4.8.4 Figure 1) similar to the springs east of the Kechut Reservoir (Madikenc group area SP80, SP83, and SP89), some springs and groundwater samples on the Amulsar ridge (ESIA Appendix 4.8.4 Figures 5 and 9), spring 8A south of Arshak Peak (location unknown), the Byuregh spring (location unknown), and groundwater well sample DDGW002 next to the Vorotan River (Drawing 4.8.2). DWJ4 also has characteristics similar to Kechut Reservoir (ESIA Appendix 4.8.4 Figure 7), the Arpa River upstream of Jermuk (Golder, 2019 Figure 1), and the Gndevaz Reservoir. No isotopic data were acquired for DWJ4, but the similarity of the major ion characteristics to waters in so many other locations (including water outside of the GSA) suggests mixing of the spring water with a significant surface water component (precipitation and/or Arpa River water).

Hydrothermal borehole LZ1 (Golder, 2019 Figure 1; location reported as south of Jermuk and east of Kechut) appears to be on a mixing line between two 2018 Jermuk samples (DWJ6 and DWJ7) and DWJ4 (and samples indicated as similar). However, the more enriched $\delta^{13}C$ of the LZ1 sample relative to Jermuk spring waters, including DWJ6 and DWJ7, indicates the composition of this spring does not result from mixing of waters. Higher gross beta of LZ1 than the Jermuk waters supports this interpretation (gross beta in GSA waters is lower than Jermuk waters).

Jermuk geothermal waters and LZ1 have distinctly more depleted $\delta^{18}O$ and $\delta^{2}H$ than GSA waters, the Arpa River, and reservoir waters (ESIA Appendix 4.8.4 Figure 4.8.27; Golder, 2019 Figure 3). The lower isotopic ratios of the geothermal waters relative to surface waters suggest the source of the springs is old meteoric water that precipitated at historically lower temperatures (larger fractionation factor) than the Present. Geothermal waters derive from long, deep flow paths. Similar depleted oxygen and deuterium isotopes of Illinois Basin groundwaters, considered to be anomalously low, were interpreted to have an origin as Pleistocene (ice age) meteoric water (Faure, 1986). The distinction in isotopic oxygen and hydrogen ratios of the geothermal waters from GSA springs and groundwaters, including springs discharging east of Kechut Reservoir, is consistent with completely separate sources, flow paths, and time frames.

The Jermuk and other geothermal waters have enriched $\delta^{13}C$, in contrast to Amulsar Mountain springs and groundwater, surface water, and precipitation that are depleted (Golder, 2019 Table 2). Other distinctions of the geothermal waters from the GSA waters are high gross beta and, for most samples, gross alpha, significantly enriched $\delta^{34}S$ (vs. distinctly less enriched surface waters and depleted signatures on Amulsar Mountain), and low and relatively consistent $^{87}Sr/^{86}Sr$ compared to Amulsar Mountain and surface waters. The sulfur and strontium isotopic data support the interpretation of long, deep flow paths that pass through mafic rocks with high/enriched $\delta^{34}S$ and lower strontium isotopic signatures than more differentiated rock types like andesite (Faure, 1986).

The high gross beta and alpha of the geothermal waters and low values for the Amulsar Mountain waters require explanation. The more evolved andesitic rocks on Amulsar Mountain should contain relatively high concentrations of the large ion lithophile elements potassium, uranium, and thorium. However, residence times of groundwater on Amulsar Mountain are extremely short compared to the geothermal waters. Accumulation of these radionuclides through preferential leaching on the long flow paths may account for the radioactivity of the geothermal waters.

Samples of the Spandaryan-Kechut outfall in 2013 (ESIA Appendix 4.8.4 Figures 7 and 8) and 2018 (Golder, 2019 Figures 1 and 2) have similar major ion composition to some Amulsar ridge spring and groundwater samples (e.g., ERW1, ERW4, RCAW399, RCAW403, and RCAW408 [ESIA Appendix 4.8.4 Figures 1, 2, 3, 4, 9, and 10; Golder, 2019 Figures 1 and 2]). However, the isotopic signatures of carbon ($\delta^{13}C$) and sulfur ($\delta^{34}S$) on Amulsar Mountain are considerably depleted relative to the tunnel outfall (Golder, 2019 Table 2). Oxygen and deuterium isotopes of the Spandaryan-Kechut outfall are depleted relative to Amulsar Mountain springs and groundwater (ESIA Appendix 4.8.4 Figure 4.8.27; Golder, 2019 Figure 3). This difference suggests the outfall water is entering the tunnel after a moderately long flow path (aged groundwater that originated at lower temperature). The strontium isotopic ratio ($^{87}Sr/^{86}Sr$) of the outfall is also lower than the Amulsar Mountain data, suggesting significant tunnel ingress is not occurring west of the mountain ridge. Isotopic data are lacking for the basaltic rocks to the north, but the low strontium isotopic signatures and relatively high/enriched $\delta^{34}S$ of the outfall suggest groundwater flow through mafic rocks. The outfall data suggest the relatively high sulfate concentration, the distinctly less depleted $\delta^{13}C$ (relative to Amulsar Mountain), the more depleted $\delta^{18}O$ and $\delta^{2}H$, low $^{87}Sr/^{86}Sr$, and the enriched $\delta^{34}S$ of the outfall are consistent with the majority of the tunnel ingress occurring from the basaltic rocks to the north. This interpretation is consistent with shallower groundwater as the Kechut Reservoir is approached, with greater potential for the tunnel to intersect groundwater.

2.1.1.6.2 Surface Water and Groundwater Quality

Surface water and groundwater quality are summarized in ESIA Sections 4.9.6 and 4.8.9, respectively. Surface water monitoring has been conducted since 2007 by Geoteam and the MNP. Geoteam began groundwater quality sampling of wells and springs in 2010. Surface water quality sampling locations are shown on Figure 4.10.1 in Section 4.9 of the ESIA. Groundwater and springs quality sample locations are shown on Drawing 4.8.2 (Section 4.8 of the ESIA).

Assuming Figure 4.10.1 of the ESIA shows current and future surface water sampling locations, the locations appear to be adequate with the exception of no location on the main tributary of the Darb River downstream of AW006 that drains the area of the mine pits. Branches to that tributary extend toward the Erato and Tigranes-Artavasdes pits. A location on that tributary just before the confluence with the Darb River or just downstream of the tributary on the Darb River would ensure all potential impacts from the mine pits are detectable.

The status of current and future groundwater sampling locations is uncertain due to the inclusion of "historical" in the title of Drawing 4.8.2 of the ESIA. The report does not explain why so few springs around Amulsar Mountain and the BRSF are monitored (compared to locations shown on Drawing 4.8.3 of the ESIA) given the importance to livestock. With respect to springs sampling locations shown on Drawing 4.8.2, which appear to have been chosen based on surface water drainage, flow in fractured rock may not follow the local topography. Given the large number of springs that can be monitored (spring melt and low flow conditions), few additional wells are recommended to monitor groundwater quality. These wells should be located north-northwest of the BRSF, southwest of the Arshak pit, and east of the Tigranes-Artavasdes pit. The additional pit wells should not be installed immediately adjacent to the pits and should be screened sufficiently deep to have saturated rock adjacent the well screens the entire year. The existing wells in the vicinity of the pits should be evaluated to ensure they are monitoring groundwater during the dry season.

Table 4.8.20 and Appendix 4.8.5 of the ESIA include the number of baseline samples of springs and wells by location and constituent. In general, the number of sampling events is extremely low (4 or less, many with 2 or less) for characterizing water quality. When examined by analyte, the majority of locations shown in Appendix 4.8.5 have only one analysis, including locations shown on Drawing 4.8.2. Natural variation and sampling and analytical error generate wide ranges of concentrations. These baseline data are extremely deficient. Meaningful statistics of analytes by location cannot be generated for comparison of future concentrations. Many drinking water locations in Table 4.8.22 of the ESIA were sampled only a few times or less.

For surface water, Appendix 4.9.4 of the ESIA provides a listing of the numbers of baseline samples by specific alphanumeric location and constituent. The numbers vary considerably by location, but many range from as few as 1 to 5, many others less than 10, far from sufficient for meaningful statistical analysis.

A statistically meaningful dataset requires about 30 observations for near-normal distributions (moderate skewness, coefficient = 1). Environmental data generally have more than a moderate amount of skew (skew coefficient > 1), requiring approximately 50 samples for a reliable two-sided 95% confidence interval around the mean (Helsel, 2005).

2.1.2 Seepage, Runoff, Groundwater Flow & Solute Transport Models

2.1.2.1 Pit Seepage Sub-Models

GRE developed a series of numerical unsaturated flow models for estimating time-transient seepage rates to the saturated zone through the rock underlying the walls and bottoms of the evolving and coalescing Tigranes-Artavasdes-Arshak pit (GRE, 2014a). The description of the modeling is concise and is generally sufficient to assess the technical merits. The models include the stages of backfilling of the Tigranes and Artavasdes pits and subsequent placement of topsoil as a growth medium for evapotranspiration according to the mine development plan. The models also simulate the seasonally-occurring pit lake in the Arshak pit resulting from precipitation, snowmelt, and runoff. The seepage flux was incorporated in the regional groundwater flow model.

The modeling was performed stepwise utilizing Vadose/W and Seep/W, two widely used, commercially-available modeling packages/tools capable of generating defensible results. The tools are physical process-based finite-element programs that, used in combination, account for atmospheric and hydrologic processes, including rigorous unsaturated flow for estimating seepage flux. Significantly, for the high elevations of the pit areas, Vadose/W accounts for the accumulation, sublimation, and melting of snowpack. At the time the modeling was performed, Seep/W did not have the capability to calculate the effects of atmospheric processes.

Vadose/W was used to develop one-dimensional (1D) column models for determining the energy and water balance at the ground surface. The models incorporate the slopes of the ground surface. The results were applied as transient water flux boundary conditions at the ground surface of two-dimensional (2D) cross-section models of the Tigranes-Artavasdes-Arshak pit. The variation in elevation of the surface of the Arshak pit lake is applied as a transient head boundary.

The cross-section Seep/W models are very good renditions of the evolving geometry of the pits and placement of backfill. The finite-element meshes appear adequate. Considering the time involved in the physical evolution of the pit geometry and backfill, the discretization of the development that is represented as stages in the models is deemed appropriate. The incorporation of topsoil is not clear at the scale of the images, but the results of the modeling show the effects on infiltration rates.

The use and manipulation of long-term climate data at the Vorotan Pass weather station to develop average daily climate inputs to the model are appropriate. The properties of the material types are based on assumptions due to limited data on the characteristics of the backfill and cover materials and lack of pumping test data. Except for the pit wall rock, the saturated hydraulic conductivities are reasonable, although they are not derived from site-specific data. The rock comprising the pit walls is naturally fractured and blast altered, but the model hydraulic conductivity of $1x10^{-6}$ cm/sec is very low and underestimated (essentially impermeable). Furthermore, the use of soil-water drainage curves, relative permeability curves, and thermal properties from the model library based on correlation with grain size distribution data and from data for materials at other sites is questionable. Materials from existing mine dumps at the Site and topsoil should have been tested for a range of parameter values. There are no supporting data or literature for the leaf area index and root depth for grass, which have a large range.

The results of the 1D models are incorrect (GRE, 2014a Table 2). The major issue is the conceptualization and high amount of evaporation from exposed rock and backfill (no soil cover). The high values of evaporation for the backfill result from simulated upward movement of soil moisture by capillary forces, a function of incorrect inputs for soil characteristics. Waste rock derived from blasting or ripping usually consists of a loose pile of material with a range of sizes, from large blocks to cobbles and pebbles. Finer grain sizes will settle through the piles, especially near the tops. Most of the incident precipitation and snowmelt infiltrates rapidly through the voids, with runoff dependent on slope and material characteristics. Water is not held under capillary forces. The uncovered VC backfill balance highlights the problem (Table 2 of GRE, 2014a). With zero runoff simulated, the precipitation/snow can only infiltrate and sublimate. The balance indicates that 450 mm of the 603 mm precipitation (net of sublimation) evaporates (75%), implying that capillary forces and soil evaporation account for the loss, or the melt water somehow ponds on the porous rock pile and evaporates. Incorrect runoff coefficients are suspected for the pit walls. Except for haul roads, where some ponding would occur, runoff from incident precipitation and snowmelt on steep walls should occur rapidly. There is virtually no potential to infiltrate with such low simulated permeability (should be higher to account for natural fractures and effects of blasting). Yet, net of sublimation, 60% to 67% of precipitation and snow melt evaporates on the pit walls. With the impermeability of the pit walls simulated, these results should show that most of the precipitation on the pit walls runs off. Much less evaporation should occur in these simulations. Soil water retention and evaporation are expected, however, for the simulation with the soil cover on the backfill.

Another problem with the Table 2 (GRE, 2014a) results is the water balance. The net infiltration based on the tabulated numbers is incorrect. Particularly large discrepancies are evident for both uncovered backfill scenarios.

With such large errors in the 1D models, the quantitative results of the 2D models are also incorrect. In a relative sense, some results of the 2D modeling appear to be qualitatively reasonable. The shapes of the curves of the time-transient infiltration rates to groundwater from the Tigranes pit are consistent with the mine plan. For example, rates peak at year 8 then decline, coincident with the pit being fully backfilled and topsoil emplacement. However, the results for the Artavasdes pit are unclear with respect to the information presented on mine planning. The cross-sections illustrating stages of pit backfill indicate that Artavasdes backfilling is finished at year 8. Peak infiltration is simulated to occur at year 11, suggesting emplacement of topsoil occurs 3 years after the termination of backfilling.

Results for the Arshak pit are incorrect. The pit will be fully excavated at year 8, at which time a closed depression will exist, and a seasonal pit lake will develop. Also, runoff from Artavazdes pit backfill toward Arshak would not occur until approximately year 8. The simulation results indicate a spike in pit bottom seepage at approximately 3.5 years, followed by a low rate, then increasing to a quasi-steady state rate. Pit wall infiltration is shown to peak at approximately year 8, then decline, which is inconsistent with the mine plan of no backfill. The seasonal differences in infiltration rates are conceptually correct.

The fluxes from the pit seepage modeling are incorrect. Use of these fluxes in the regional groundwater flow model results in incorrect assessments of impacts to groundwater levels and springs. Furthermore, solute transport simulations would severely underestimate potential impacts to groundwater and springs from acid mine drainage.

Due to overestimating evaporation and underestimating the runoff, water and mass fluxes reporting (pumped) to the PTS are underestimated, the amount of makeup water is overestimated, and the timing for requiring the PTS is potentially overextended/delayed. The conceptualizations and estimated evaporation, runoff, and groundwater infiltration fluxes are inconsistent with the updated SWWB presented as Appendix 6.10.1 of the ESIA (Golder, 2018).

2.1.2.2 BRSF Runoff Sub-Model

GRE (2014c) presents numerical modeling conducted to estimate time-transient runoff rates from the BRSF and undisturbed ground surface and generated functions for spring and seep flows with the objective of determining the total quantity of water reporting to the BRSF toe pond. The description of the modeling is sufficient to assess the technical merits.

The modeling was performed utilizing Vadose/W. GRE employed 1D column models to determine the energy and water balance at the ground surface for various slopes and surface materials under typical year, wet year, and dry year conditions using long-term climate data at the Vorotan Pass weather station. The use and manipulation of long-term climate data at the Vorotan Pass weather station to develop average daily climate inputs to the model are appropriate, but the wet and dry year inputs are questionable (See Section 2.1.1.1.3 of this report). A 2D Vadose/W model was used to estimate runoff from the undisturbed ground surface. The evolving BRSF and shrinking surface area of undisturbed ground surface were incorporated in the modeling to estimate the time-transient runoff rates. Noteworthy is the stated preliminary status of the modeling due to limited data on spring and seep flows.

GRE (2014c) states that functions were generated representing flow for perennial and ephemeral springs throughout the year. The perennial spring flows were correctly assessed to be part of the total flow reporting to the BRSF toe pond. However, ephemeral spring flows were assumed to abate after the BRSF expanded across their location. This assumption affects the water balance and is not necessarily correct because the sources of discharge may be beyond the footprint of the BRSF, including mine pit areas. Also, the paucity of data on spring flows does not justify a maximum seasonal flow rate for the ephemeral springs occurring at a different time than the perennial springs.

GRE (2014c) indicates that the mine waste was assumed to consist of a wide range of grain sizes to maximize runoff and, thereby, add a conservative factor to the model. The properties of the material types are based on assumptions due to limited data on the characteristics of the backfill and cover materials. The model assigned saturated hydraulic conductivities (Table 2 of GRE, 2014c) are reasonable, assuming the low value for the argillized LV backfill represents the 0.5 m thick compaction zone that is presumably a design feature at the top of the PAG rock. However, the selection of other model material properties is questionable (See Section 2.1.2.1 of this report). The conservatism for the sake of calculating runoff is not conservative for estimating seepage (See Sections 2.1.2.1 and 2.1.2.3.1 of this report). Also, as noted above, there are no supporting data or literature for the leaf area index and root depth for grass.

Figure 11 (GRE, 2014c) includes runoff results from LV waste rock for a typical year. GRE (2014c) states that very little runoff is generated by the model (an expected result) due to the coarse texture and relatively high permeability of the waste, with the potential for subsequent evaporation of soil moisture. This statement underscores the misconception about the fate of the moisture that infiltrates, which is manifested in the simulations as high soil moisture evaporation and low seepage rates (See Sections 2.1.2.1 and 2.1.2.3.1 of this report). The evaporation is inconsistent with the coarse texture and high permeability of the exposed waste rock pile.

Due to overestimating evaporation and underestimating the runoff, water and mass fluxes reporting to the PTS are underestimated, the amount of makeup water is overestimated, and the timing for requiring the PTS is potentially overextended/delayed. The conceptualizations and estimated evaporation and runoff fluxes are inconsistent with the updated SWWB (Golder, 2018).

2.1.2.3 BRSF Seepage Sub-Model

2.1.2.3.1 Seepage Through Waste Rock

GRE performed numerical unsaturated flow modeling to estimate time-transient seepage rates through the BRSF during operations and the post-closure period (GRE, 2014b). The description of the BRSF development and the modeling are adequate to assess the technical merits.

The modeling was performed utilizing Vadose/W, described in Section 2.1.2.1 of this report. GRE utilized the results of 1D column models that estimate the amount and timing of infiltration into the materials that will be exposed at the surface of the BRSF at various stages and after closure. These models were previously developed to estimate runoff from the BRSF (GRE, 2014c). The results were incorporated into a series of 2D Vadose/W models as transient water flux boundary conditions at the ground surface. The 2D models represent the evolution of the BRSF along a northeast-trending cross-section that approximately follows the axis of the BRSF valley, where the greatest thickness of waste rock will be deposited.

An example was presented of an infiltration function from the 1D modeling for the upper volcanic rock waste during operations (GRE, 2014b Figure 1). The plotted results show an infiltration peak corresponding to the April-May snowmelt event, followed by summer and early fall negative infiltration (evaporation from the waste rock). The text clarifies that a portion of the moisture near the top of the waste rock is lost to the atmosphere. This evaporation (attaining a rate of about 1460 mm/year), resulting from capillary forces drawing moisture to the surface of the waste rock, is unrealistic and supports the belief that the evaporation from the pit backfill, discussed in Section 2.1.2.1 of this report, results from incorrect inputs for rock pile properties.

A 2D infiltration function (GRE, 2014b Figure 2), representing post-closure conditions with a soil cover, shows no evapotranspiration during the summer months because the function was edited to remove this water loss. The statement in the text that “it is unrealistic to assume so much water could be removed by evaporation” is an awareness that the model is incorrect. The problem caused by the incorrect soil characteristics for the VC waste rock (incorrect conceptualization of a loose rock pile) was compounded by the conceptually correct implementation of capillary forces in the soil cover. Moisture was being supplied to the cover soil from the underlying rock. The alteration of the 2D function to remove evaporation, however, did not correct the model. The lack of elevated infiltration during the spring snow melt (GRE, 2014b Figure 2) is the result of the combined effects of the incorrectly simulated capillary forces in the VC waste rock and the correct implementation of capillary forces in the overlying soil cover.

The calculated volumetric fluxes that report to the base of the BRSF are greatly underestimated due to incorrect model parameterization. The underestimated water fluxes translate to underestimated mass fluxes related to contact of the seepage with the acid-generating rocks. These underestimates negatively impact the calculated net water fluxes and concentrations resulting from the mixing of ARD with fluxes from the springs and seeps beneath the BRSF. Consequently, water and mass fluxes reporting to the PTS are underestimated, the amount of makeup water is overestimated, and the timing for requiring the PTS is potentially delayed.

2.1.2.3.2 Seepage to Groundwater

GRE (2014g) simulated seepage to groundwater through the BRSF foundation (clay liner) beneath the overdrain (consisting of 5m of VC rock) under the assumption that some of the seepage passing through the waste rock pile will continue migrating vertically rather than flow along the base of the overdrain. Seepage through the BRSF foundation was evaluated for four conditions (GRE, 2014g Figure 2): 1) basalt underlying the clay liner, LVA underlying the clay liner, springs discharging through LVA underlying the clay liner, and the stream carrying spring discharge water on the clay liner underlain by LVA. The seepage was simulated for 1,000 years. The descriptions of the modeling are incomplete.

Simulations of seepage into the LVA and basalt were performed with Vadose/W based on the same material properties of the waste rock and other model parameters that were used to estimate seepage rates through the waste rock pile described in Section 2.1.2.3.1 of this report. The boundary conditions at the base of the models are not provided in the text. A simple Vadose/W model was used to simulate seepage along a profile through the area of the stream channel based on simulated lateral flow through the VC overdrain on the clay liner, with assumptions of head at the upstream and downstream locations of the channel (implemented with constant heads) and a single water level in the underlying argillically-altered LV (implemented with constant head). The area of the BRSF foundation underlain by springs was not modeled due to the interpretation that seepage would be prevented by the upward vertical gradients associated with groundwater discharging at ground surface.

Based on the information provided, it cannot be determined whether the simulated seepage rates into the basalt and the argillically-altered LV are conservative or underestimated. The simulated seepage fluxes reporting to the base of the waste rock pile are underestimated for the same reasons described in Section 2.1.2.3.1 of this report. However, without knowing the boundary conditions at the base of the pile, it cannot be determined if the models are simulating saturated head building on the clay liner without potential for lateral drainage through the VC overdrain (conservative). If boundary conditions provide for lateral drainage, the slope of the compacted clay surface is unknown, but the seepage fluxes to groundwater are likely underestimated due to the underestimated fluxes reporting to the base of the rock pile. Noteworthy are seepage rates through the LVA that are higher than seepage rates through the basalt (GRE, 2014g Table 1). The basalt is considerably more permeable, and both media are overlain by clay. The clay placed over the basalt is modeled with a hydraulic conductivity of $1x10^{-5}$ cm/sec. The hydraulic conductivity assumed for the compacted clayey soil foundation material in GRE (2014c) is $8.4x10^{-7}$ cm/sec. The higher seepage rates through the LVA are inconsistent with these values. The simulated seepage rate to groundwater beneath the area of the stream is low, as expected, due to preferential lateral flow through the VC underdrain and slotted pipes.

2.1.2.4 HLF Solute Transport Sub-Model

Golder (2014b) presents an assessment of the potential impacts to groundwater and surface water that could result from leakage through the membrane liners of the heap leach pad (HLP) and pregnant solution pond (PSP) during operations through post-closure. The description of the design of the HLF, the conceptual model, and the solute transport modeling are adequate to assess the technical merits.

The analyses were performed with the assistance of the GoldSim Contaminant Transport Module. The modeling software is purported to have been used to address complex contaminant transport problems worldwide, especially in radioactive waste management, mining, and water resources. An overview of the modeling tool is provided in the HLF assessment report, which indicates the model utilizes analytical solutions. The use of analytical solutions may be acceptable for simulating local leakage scenarios and approximating local vertical fluxes, particularly with the stochastic algorithms, but the application of the model alone to simulate transport in the complex saturated zone within the GSA is questionable, especially with the existence of a numerical groundwater model (FEFLOW used for modeling groundwater flow and could have been coupled with GoldSim). The numerical groundwater model should incorporate water and contaminant fluxes from all potential sources to produce an integrated assessment of impacts to groundwater and surface water. On this basis alone, the results of the GoldSim transport modeling may be dismissed. However, there are other overarching issues with the modeling, primarily with the assumed source concentrations.

A major flaw in the transport modeling is the absence of the chemical analysis of the pregnant leach solution (PLS). Golder (2014b Section 2.1.2.1) states that the attenuation mechanisms[10] of weak acid dissociable (WAD) cyanide within the heap are complex and are only reliably assessed through laboratory testing of the leach process or in heap operation. Compounding the source term issue is the assumption that the chemical analyses (Golder, 2014b Table 2) of barren leach solutions (BLS) are suitable substitutes for the PLS. That assumption is incorrect due to the processes involved in separating the gold from the PLS. Furthermore, assuming the concentrations of metals in the PLS are up to 2 times the concentrations reported in the BLS is unsatisfactory because the factor differences between the two analyses of BLS are much greater than 2 for many of the constituents.

The heap leach solution (HLS) will be in a closed loop with zero discharge. Volume control is through evaporation. Loading with sodium cyanide, hydrochloric acid, sodium hydroxide, and lime (to crushed ore) occurs continually at various stages. Drainage from the BRSF will also be added to the leach solution for the first 5 years, contributing additional load (e.g., sulfate and metals), and there will be ammonium nitrate residue from blasting. After 10 years, the concentrations of many constituents, including metals, will be higher than shown in Golder (2014b Table 2).

Other issues with the BLS and final detoxified solutions Golder (2014b Table 2) include total alkalinities that are not the sums of the components (bicarbonate, carbonate, and hydroxide). Particularly concerning is the zero bicarbonate in solution 61790. There is also charge balance error in the solutions.

The assumptions for the vertical flow modeling are conservative. However, the absence of results from unsaturated flow modeling of infiltration through the post-closure cover at the time the HLP assessment was performed is unsatisfactory.

[10] Volatilization, complexation, and precipitation

Simulated transport species omit chloride, the most conservative/mobile solute in groundwater. Furthermore, selenium should be included in transport simulations due to the detrimental impacts to fish (USEPA, 2016). The significance of these omissions cannot be determined in light of the uncertainty in the overall assessment and in the modeling conceptualizations.

The text is unclear with respect to Scenario 1 shallow impacted groundwater that emerges in the stream bed southwest of the HLF. In one description of the modeling (Golder, 2014b Section 2.3), the constituent mass is not discharged to the Arpa River “as this is considered in Scenario 2”. If that is the case, the simulated extended path length through the subsurface to the Arpa River incorrectly provides additional attenuation and delay that would not occur in surface water. In Section 3.4.3 and Section 4.0, for Scenario 1, this discharge is stated to be captured before discharging to the Arpa River. It is unclear what infrastructure is planned for this capture and how or why additional impacted shallow groundwater would not discharge further to the southwest in the stream bed for flow into the Arpa River.

In Section 3.4.3.3 (Golder, 2014b), there is a discussion about monitoring streamflow and quality of the shallow groundwater emerging in the drainage southwest of the HLF during operations. Golder (2014b) states that if leakage is detected and modifications to the HLF operations do not result in water quality improvements, then other industry-standard seepage mitigation measures would be implemented to prevent offsite migration of shallow groundwater. Golder (2014b) does not specify or provide details on the seepage control measures nor does it explain as to how changes in HLF operations can mitigate a design or construction flaw buried beneath the heap. Moreover, the approach to implement unspecified mitigation measures to prevent offsite migration of shallow contaminated groundwater is a reactive rather than proactive approach to protecting the Arpa River.

2.1.2.5 Regional Groundwater Flow Model

Golder constructed a three-dimensional groundwater flow model for the GSA with the intention of improving understanding of the hydrogeologic setting of the proposed mine site and to estimate groundwater inflow to the mine pits (Golder, 2014a). The report describes the model construction, inputs, calibration to baseline conditions, and predictions of impacts to groundwater quantity for operational and post-closure phases of the mine. Particle tracking was used to illustrate simulated groundwater flow pathways. The report was evaluated for the technical merits of the model with respect to the Site hydrology and hydrogeology, its reliability for predictive analysis, as well as the numerical modeling procedures. The evaluation presented in the following text addresses the most significant aspects of the modeling.

Noteworthy is that the model was not used as a tool in the planning phase of locating mine facilities for minimizing risk to the environment (e.g., Myers, 2016). A significant omission of the numerical modeling is the performance of solute transport simulations for predicting impacts to the quality of groundwater and surface water.

The modeling was performed with FEFLOW, a widely used, commercially-available groundwater modeling tool capable of generating defensible results. Finite-element groundwater modeling tools are uniquely suited for incorporating complex geologic structure. FEFLOW can simulate fully-saturated and variably-saturated conditions and contaminant transport. Capabilities for facilitating parameter estimation, highly parameterized inversion, and uncertainty analysis (e.g., Doherty, 2010) are integrated in the commercial modeling package.

The model domain is delineated by groundwater divides of the major rivers along almost the entire perimeter and is appropriate for assessing potential environmental impacts of the mine. Discretization by the numerical mesh is generally appropriate over the majority of the GSA for a model of this scale.

Constant head boundaries were set along the major rivers with head corresponding to the channel bottom to a depth of 100 meters (i.e., all model layers within 100 m depth of the surface were assigned the same head). This approach is incorrect because it simulates perfect hydraulic connection between the rivers and rock to 100 meters depth (i.e., precluding upward hydraulic gradients). It is inconsistent with the conceptual model illustrations showing upward gradients beneath the rivers as expected for groundwater flow paths to gaining rivers in this setting. Flow paths illustrated by results of particle tracking simulations are depressed because the effects of upward vertical gradients that occur near the rivers are artificially eliminated beneath the rivers in the flow simulations (due to this incorrect boundary condition).

Section 4.9.5 of the EISA states that numerous minor perennial tributaries originating on the slopes of Amulsar and the plateau to the east of the Vorotan feed the Darb and Vorotan Rivers. These perennial streams should have been included in the model.

A potentially unnecessarily long no-flow boundary was used along the southern perimeter, forcing flow parallel to this boundary to the northwest and southeast. A boundary condition that permits discharge (seepage face) at appropriate elevations could have been utilized along the upper Darb and the Porsughlu River (assuming both rivers are perennial in those locations) that flows to the southeast toward the Spandaryan Reservoir for nearly the entire length of the simulated no-flow boundary. No-flow would be appropriate for a very short length near the topographic divide. The impact of the long no-flow boundary on simulated flow from Amulsar Peak cannot be determined based on available information.

Seepage faces were used to simulate perennial springs discharges. Appendix 6.9.1 of the ESIA states that the elevations of the perennial springs were not used as groundwater elevation calibration points. The seepage faces must be defined with appropriate elevations. The statement is troubling because it suggests imprecision in setting the elevations to ensure the model simulates springs discharge (i.e., at lower elevations than the springs).

In principle, the hydrogeologic conceptual model is incorporated into the model. However, the model is an extremely generalized representation of the hydrology and hydrogeology of the GSA. The model embodies the principal topographic and hydrologic elements of the conceptual model comprised of Amulsar Mountain surrounded by the Arpa, Vorotan, and Darb Rivers. Discharge is simulated to the rivers and perennial springs. Except for local higher recharge in the BRSF valley and adjacent basins (250 mm/yr), the final calibrated net recharge is uniform at 200 mm/yr. This uniform recharge rate is generally low, with respect to winter (baseflow) measurements of the major rivers (Table 4.8.13 in Section 4.8.6 of the ESIA), from which annual values were calculated, which reportedly underestimate of the annual recharge.

Five conceptual hydrogeologic units were delineated in the GSA: Colluvium, VC, LVA, LV, and Basalt. With the exception of distinguishing a deep section of LV for assigning model properties, each of the five hydrogeologic units is represented by a single set of hydraulic properties, i.e., all six model units are numerically homogenous, in spite of the hydraulic test data showing 4 or more orders of magnitude variation in hydraulic conductivity for each rock type. This deficiency can have a significant effect on the model predictions (e.g., will not identify preferential flow pathways).

The geology in the pit areas is poorly represented. Faults are completely absent in the model. Geologic modeling of the Amulsar Mountain ridge area (Holcombe, 2013) reveals a level of simplicity defined by a major fault architecture with large displacements (> 250 m) and large-scale slabs or stacked sequences of VC and LVA separated by thrust fault planes that should have been incorporated in the groundwater model. Some LVA panels were correlated through multiple fault blocks. Complex structural blocks could be represented as simple hydraulically distinct units for calibration. The major high-angle normal faults and low-angle thrust faults are likely barriers to groundwater flow, which is supported by the occurrence of abundant clay gouge inferred to have been transported during slip along LVA units. Some faults may be conduits for groundwater flow. Incorporation of these structural and lithologic elements, with calibration to water levels in wells screened in discrete lithologies and discharges of springs, holds the potential to understand many of the major ephemeral springs and better quantify net recharge to the underlying regional groundwater flow system.

The simplistic numerical representation of the subsurface in the existing model is inadequate for making quantitative predictions. Notwithstanding this inadequacy, numerous quantitative predictions, which are unreliable, were made. Transient simulations were performed to estimate pit inflows, but the model is also a poor predictor because a transient calibration was not performed, such as simulation of a pumping test.

The baseline model (calibration) represents average annual conditions as a steady-state simulation. The model was calibrated to the average groundwater elevations recorded in monitoring wells in the GSA[11]. Even with this simplification of site conditions and water level targets, there are many significant calibration errors (differences between simulated and target water levels). Twenty-two of forty-one calibration targets (54%) have errors of 25 meters and more, and fourteen targets (34%) have errors of 40 meters and more, ranging up to 96 meters (twice the maximum recorded seasonal range in water levels). Even without considering recorded seasonal differences in groundwater levels up to 48 meters in wells, the steady-state model, purported to represent average conditions, with such large calibration errors to predict groundwater elevations is unreliable.

Estimated errors in groundwater levels up to 25 m for the purpose of calibration are excessive. The report indicates that well elevations were determined in 40% of the locations with a hand-held GPS and assigned an incremental error of 20 m. These devices are typically accurate within 10 m. The liberal estimated error appears to be a justification of the large model water level errors.

Despite the large model water level errors, the model was used to estimate operational water levels beneath the BRSF area (simulated baseline water level errors up to 80 m), the HLF area (simulated baseline water level errors up to 37 m), and the mine pits (simulated baseline water level errors up to 90 m). Furthermore, the baseline model results were used to delineate the distribution of head at or above ground surface across the GSA which, only locally, roughly corresponds to the locations of springs. With such large errors in calibration water levels, the

[11]This procedure is inconsistent with a statement made by Lydian representatives during the March 28, 2019 presentation that model calibration was based on springs' discharges, not groundwater elevations.

model is a poor indicator of head above ground surface and a poor indicator of the effects of mining activities on groundwater levels and groundwater flows (springs, river discharges, pit inflows). Noteworthy are the omissions of springs elevations and discharges as targets in the calibration (inconsistent with statement made during Lydian's March 28, 2019 presentation). Golder (2014a) acknowledges the model's inability to predict pit inflows, yet pit inflows and the impacts of pit dewatering on water levels and on springs discharges and river flows were reported.

Extremely large changes in head are predicted from reduced recharge over the footprints of facilities (up to 69 m beneath the BRSF in the LVA, greater than maximum recorded seasonal changes). These results are indicative of calibrated hydraulic conductivity values that are too low, not reflecting fracture permeability and connectivity. Section 4.8.4 of the ESIA states that hydrographs for wells in the BRSF site indicate that groundwater levels rise rapidly in the Spring in response to snowmelt and decline rapidly following snowmelt. This behavior is indicative of fracture permeability and connectivity. The predicted changes in groundwater levels are unrealistic. Fractures beneath the BRSF are connected with fractures outside the BRSF footprint. Furthermore, model hydraulic conductivity values are directly proportional to model recharge values, and the recharge is low.

Especially conspicuous is the $1x10^{-8}$ m/s hydraulic conductivity of LVA (Golder, 2014a Table 4), which is essentially impermeable. Considering the extent of structural deformation of the volcanic rocks on Amulsar Mountain, the fracture permeability in the LVA, which will be higher than the matrix permeability, will control the groundwater flow. Argillized tuffaceous rocks at Yucca Mountain, for example, have hydraulic conductivities ranging from approximately $1x10^{-5}$ to $1x10^{-4}$ m/s (Gelden, 2004). Table 4.8.1 of the ESIA shows a high end of $3x10^{-5}$ m/s from tests in LVA. Another conspicuous calibrated hydraulic conductivity value is for the VC ($2x10^{-7}$ m/s), which is lower than unaltered LV ($6x10^{-7}$ m/s). This silicified rock is brittle and highly fractured (average RQD of 0.40; Table 1, App. 6.9.1), especially considering its occurrence in the area of greatest structural deformation, and thus should have a higher hydraulic conductivity than the unaltered LV. Table 4.8.1 of the ESIA shows a high end of $3x10^{-4}$ m/s from tests in VC. The unaltered LV has a calibrated hydraulic conductivity of $6x10^{-7}$ m/s. Table 4.8.1 of the ESIA shows a high end of $2x10^{-4}$ m/s from tests in LV. For fractured rocks, the assumed uniform hydraulic conductivity anisotropy ratio (K_h/K_v) of 100 for the LV is conspicuously high and is contributing to the low calibrated recharge. The basalt, described as intensely fractured (average RQD of 0.19), is missing from Table 4, and cannot be evaluated. The colluvium hydraulic conductivity is reasonable, but it is unclear why wells within the colluvium were not included in the calibration.

An outdated approach (ASTM, 2016) was used to perform model sensitivity analysis. The results were not used or intended to be used to collect additional data for the most sensitive parameters to better constrain the model (Myers, 2016), nor were the results used to guide calibration of the model because the procedure was performed after calibration. The results determined that the model is very sensitive to the hydraulic conductivity of the colluvium, yet water levels in the colluvium were not used in calibration. The problem with this type of sensitivity analysis is that the model is no longer calibrated after making a large change to a single parameter. The modified model cannot be used with any confidence to evaluate uncertainty of predictions.

Given the complexity of the geology of the GSA, the model should be calibrated using highly parameterized inversion (regularization techniques) to generate the expected heterogeneous and variably anisotropic hydraulic conductivity values for each hydrogeologic unit in order to match measured heads and flows. The uncertainty of the results of predictive simulations based on the non-unique solution (all models are non-unique) could then be evaluated. Predictive uncertainty analysis determines the set of possible solutions that similarly meet the calibration objective function (the sum of squares of model errors), and predictive results are generated for each solution as part of risk analysis.

The model is a qualitative or screening tool, at best, for illustrating the generalized configuration of the potentiometric surface, generalized groundwater flow paths, and conceptual responses to mining and associated operational activities on groundwater levels. The model certainly does not contribute to understanding the hydrogeologic setting of the proposed mine. If a quantitative model was the objective for predicting changes in water levels and flows, more hydraulic testing (especially pumping tests) should have been performed, and considerably more effort should have been devoted to incorporating the main structural and stratigraphic elements in the pit areas. Long-term, large-scale pumping tests should have been performed in the areas of the mine facilities and pits at various depths, as well as several in each rock type across the GSA.

Surface water and groundwater are interconnected. Water is exchanged in both directions. There are a host of factors influencing groundwater recharge, which varies significantly in space and time at all scales. Assuming some fixed amount of water percolates through the ground uniformly across large areas of the site and recharges groundwater at a rate that is constant with time is an overly simplistic approach that leads to poor model representation of subsurface properties and unreliable conclusions about surface water and groundwater. Given the scope of the Mine and its potential impacts on the environment, watershed modeling should have been employed. Recharge values are best constrained using an integrated hydrologic modeling approach which links watershed modeling and groundwater modeling.

The report (Golder, 2014a) states that the model indicates the Spandaryan-Kechut tunnel intersects the water table along its length, but with little influence on the water table in the south and center of the model. Noteworthy are the considerably depleted isotopic signatures of carbon ($\delta^{13}C$) and sulfur ($\delta^{34}S$) on Amulsar Mountain relative to the tunnel outfall (Golder, 2019 Table 2). The strontium isotopic ratio ($^{87}Sr/^{86}Sr$) of the outfall is also lower than the Amulsar Mountain data, suggesting significant tunnel ingress is not occurring west of the mountain ridge. Isotopic data are lacking for the basaltic rocks to the north, but mafic rocks typically have lower strontium isotopic signatures than more differentiated types (e.g., andesite) and high/enriched $\delta^{34}S$ (Faure, 1986). The outfall data suggest the relatively high sulfate concentration, the distinctly less depleted $\delta^{13}C$ (relative to Amulsar Mountain), and the enriched $\delta^{34}S$ of the outfall are consistent with the majority of the tunnel ingress occurring from the basaltic rocks to the north.

A notable inconsistency in the report (Golder, 2014a) is apparent in the model calibration section with respect to estimated percentages of the catchments of the rivers within the model domain. In this section, the text states that approximately 20% of the Vorotan River, 60% of the Arpa River, and 45% of the Darb River catchments lie within the model domain. These percentages contrast with 15% for the Vorotan River, 15% for the Arpa River, and 30% for the Darb River stated in Section 4.6. These discrepancies suggest adjustments of the estimates were made to suggest that simulated Vorotan and Arpa discharges are correct.

The model does not correctly represent the GSA water balance. Total recharge is low with respect to estimated river baseflows. Furthermore, the model is intended to represent average annual conditions (calibration to average groundwater levels). The average levels incorporate high late spring and early summer groundwater levels resulting from infiltration of spring snowmelt. Much of this infiltration discharges as ephemeral springs and is not part of baseflow. In order for the model to support these higher average groundwater levels, in combination with the low recharge, low hydraulic conductivity values were required (lower than fractured rock). Less water is moving through the simulated rocks than the actual quantity. Furthermore, the simulated rates of flow and transport (advective velocities in the particle tracking simulations) are too low.

2.1.3 Water Resources Impacts Assessment

Potential impacts to surface waters and groundwater from the BRSF, the HLF, and the mine pits were estimated with the assistance of sub-models and water balance calculations. The sub-models are addressed in Section 2.1.2 of this report. The assessments pertain to springs, rivers, reservoirs, community water supplies, and the Spandaryan-Kechut tunnel. Emphasis is placed on the post-closure period for the analysis of impacts. The impacts assessments are not based on an integrated approach that includes all sources of contaminants. Limited solute transport simulations were made using an analytical model instead of the regional numerical groundwater flow model to simulate the complex system.

2.1.3.1 BRSF

Section 2.1.2.3 of this report discusses the simulated water balance for the BRSF (GRE, 2014b,c). The calculated volumetric fluxes that report to the base of the BRSF are greatly underestimated due to incorrect parameterization of the infiltration model. The underestimated water fluxes translate to underestimated leachate mass fluxes related to contact of the infiltration water with the acid-generating rocks. Based on the information provided by GRE, the potential seepage rates to, and mass loading of, groundwater are also underestimated.

Geochemical modeling was performed to estimate the post-closure water quality that may seep to groundwater beneath the BRSF (GRE, 2014g). The description of this modeling, including treatment of detection limits and the basis for the initial water qualities and oxygen penetration depth, is essentially the same as summarized in Section 2.1.3.3.2 below for seepage through the backfill in the Tigranes-Artavasdes pit. However, the specifics of the HC test solutions and the resulting compositions of the initial solutions (VC and LV) are not included. Otherwise, the same charge balancing procedure was used (with fluoride and sodium) and the same equilibrations under oxic then anoxic conditions were performed. The solutions were mixed after the oxic equilibration. Appendix C of this report (table showing required PHREEQC model details) shows the equilibrated solid phases. In contrast to the cover on the backfill of the Tigranes-Artavasdes pit, the BRSF ARD rock is overlain by 0.2 m of topsoil, 1 m of clay, and 0.5 m VC waste rock.

The text of the report (GRE, 2014g) states that simulated leachate water quality is consistent with samples of long-term ARD reactions that are occurring in unmitigated LV waste piles located in Site 13 and Site 27. The simulated pH of the leachate is 3.0, similar to Site 27 leachate. Most of the simulated concentrations are much greater than the observed concentrations, which is consistent with a much longer vertical flow path than the existing waste piles. The notable exception is iron. The simulated concentration arriving at the base of the waste pile is only 0.5 mg/L, compared to 3.2 mg/L in the Site 27 leachate (ESIA Appendix 4.6.2 Table/Appendix F-1), which has a similar pH of 3.3. This difference is indicative of inappropriate specification of iron phases in the equilibrium modeling (see discussion of Pit Water Runoff below).

Assessment of impacts to groundwater was not done, i.e., no mixing calculations were performed. Transport was not simulated in the regional groundwater model, nor by any other means.

2.1.3.2 HLF

The assessment of potential impacts from the HLF is discussed in Section 2.1.2.4 of this report. Use of inappropriate source concentrations is the major issue with the solute transport modeling. Also, the assessment does not integrate potential impacts from the BRSF and the mine pits.

2.1.3.3 Mine Pits

The water fluxes (runoff, infiltration through backfill, seepage to groundwater) from the pit seepage modeling of the Tigranes-Artavasdes-Arshak pit are significantly underestimated (Section 2.1.2.1 of this report). Insufficient information is provided in the report for the Erato post-closure pit water balance (Golder, 2014c) to fully assess the pit inflows, the pit lake level and volume, and the calculated seepage rate to groundwater. However, perched water inflows are based on the incorrect, low recharge rate determined by the groundwater model calibration. Noteworthy is that only 40% of precipitation on the pit walls was assumed to report to the pit bottom based on a water balance for the HLF (cited report[12] was unavailable). This assumption is suspect because the pit walls and the HLF have very different surface properties and elevations. These issues suggest the steady-state pit lake surface water elevation is underestimated. Moreover, based on neglect of the effect of the head of water on the pit floor, the seepage rate would be underestimated. The seepage rate to groundwater from the Erato pit lake is underestimated.

Solute transport simulations based on the estimated pit seepage fluxes underestimate potential impacts to groundwater and surface water (independent of uncertainties introduced by questionable source concentrations, other assumptions, and approach). Predictions of impacts require an integrated approach that includes loading of constituents to groundwater and surface water from all potential sources. The impacts assessment presented by Golder (2014d) only considers the loading from the mine pits and thus the overall impact on the groundwater cannot be adequately assessed.

Geochemical modeling of pit water runoff was performed to determine the quality of water reporting to sumps in the pits and ultimately to the PTS (GRE, 2014e) during operations. This pit water quality is also relevant to the lake that will develop in the Erato pit (and seep to groundwater) during operations (although the emphasis of the impacts analysis is on the post-closure period). The Erato pit will be partially backfilled with non-acid generating rock near the end of mining. The results of geochemical modeling the water quality of the backfilled Erato pit are summarized in Golder (2014e). This water quality is used in the post-closure impacts

[12] GRE, 2014. AMULSAR SITE 28 HEAP LEACH FACILITY WATER BALANCE CALCULATIONS.

analysis that includes seepage to groundwater from the backfilled Erato pit. Geochemical modeling of the water quality of the Tigranes-Artavasdes pit backfill seepage and Arshak pit seepage is summarized in GRE (2014f). These water quality results are also used in the post-closure impacts analysis.

2.1.3.3.1 Pit Water Runoff

Inappropriate results of the runoff water quality modeling (GRE, 2014e) can be illuminated with some examples of the multitude of issues identified with this modeling as noted below:

i. The chemistries of the waters contacting LV in the backfill (Tigranes-Artavasdes) and the pit walls are represented by ARD-74C HC test solutions (weeks 5 and 10, respectively), which were selected as purportedly conservative solutions. The solutions from this sample with 2.1% pyritic sulfur are not necessarily conservative, with many LV samples having more than 4% pyritic sulfur, ranging up to 9.5%. A better choice for conservatism would be the HC test solution from ARD-76C with 4.2% pyritic sulfur.

ii. The pH levels (3.7 for backfill and 3.5 for LV) at weeks 5 and 10 are high and chemical concentrations of the selected, less conservative ARD-74C solutions are very low, relative to solutions from weeks 14 to 20, when pH dropped to about 2.7. Sulfate, for example, increased from approximately 100 mg/L in weeks 5 and 10 to over 1,000 mg/L in later weeks. Iron increased from less than 10 mg/L to more than 150 mg/L. For the operations period, the rapid rate of mining is acknowledged in the choice of early HC test results.

iii. Three of the 4 initial solutions for simulated mixing of runoff waters (LV, backfill, VC, and colluvium) have significant charge imbalances (e.g., requiring nearly 7 mg/L chloride addition to VC), indicating poor and/or incomplete analyses. SiO_2 is missing for two solutions[13], and nitrogen species are missing for all solutions. Sodium (3.6 mg/L) was added to the backfill solution for charge balance. Changing concentrations significantly to charge balance solutions affects activity coefficients and saturation indices.

iv. The individual solutions were appropriately equilibrated with atmospheric oxygen and carbon dioxide, but many minerals, including multiple iron-bearing phases with saturation indices > 0 (Appendix C), were permitted to precipitate in each solution **before** mixing (i.e., as the water runs into the pit sumps). The iron phases include magnetite, hematite, and goethite, which have slow growth kinetics at surface temperatures (Zhu and Anderson, 2002). Cupric and cuprous ferrite (oxides) are also kinetically inhibited. These phases should not be specified to precipitate before or after mixing.

v. The mixed pit runoff water has extremely low iron concentrations (ferric iron 10^{-8} to 10^{-9} mg/L; ferrous iron 10^{-12} to 10^{-13} mg/L)[14] due to the strong mineralogic controls. For

[13] c.f., SiO2 for one LV SPLP is 8.3 mg/L, “Si” for Site 27 waste leachate is 11.3 mg/L, and Site 13 mine portal leachate is 12.1 mg/L (ESIA Appendix 4.6.2 Tables/Appendices D-1 and F-1).

[14] These concentrations are unrealistic and are less than iron concentrations in the Amulsar surface water, groundwater and rain water (Golder, 2019).

comparison, iron in Site 27 waste leachate with a pH of 3.3 is 3.2 mg/L (ESIA Appendix 4.6.2 Table/Appendix F-1). Silica (SiO_2) was not simulated.

2.1.3.3.2 Tigranes-Artavasdes Seepage and Arshak Pit Seepage

The water quality of seepage through the Tigranes-Artavasdes and Arshak pits (GRE, 2014f) were each modeled differently. The closure plan includes a 0.5-meter cover to minimize infiltration and oxygen penetration into the backfill of the Tigranes-Artavasdes pit. The modeling is based on the assumption that seepage water will only be impacted by the LV rock of the backfill. Assumptions include a limited zone of oxygen penetration in the backfill for ARD generation and equilibration of the seepage in the underlying anoxic zone of the backfill. In the Arshak pit, runoff water will collect at the bottom of the pit, where it is in contact with LV waste rock prior to seepage to groundwater. ARD generation on the pit walls and at the pit bottom are inputs to modeling anoxic conditions of the seepage below the pit bottom. Details of the modeling are not provided. However, some obvious deficiencies and inconsistencies are addressed below.

The compositions of HC test solutions were used to define initial solutions for runoff and seepage water. The loading rates were determined (GRE, 2014f) by averaging the weekly concentrations of all constituents, and then averaging each constituent's weekly averages. Concentrations are not loading rates. Loading rates are mass/unit mass per unit time. The loading rates were then multiplied by the total weight of rock and divided by the total seepage volume in order to simulate the initial seepage water quality. There is no discussion of the mass of rock contacted by seepage through the backfill, or assumptions about mass in contact with runoff on the pit walls (e.g., thickness), or the mass of backfill in contact with the runoff water at the bottom of the pit. Treatment of non-detectable concentrations was inconsistent. Sulfate was assigned ½ the detection limit and the other constituents were assigned zero. The text states that a buffer concentration was applied to alkalinity around detected values of 1 mg/L. This statement is not clear, and it appears that the stated concentration was arbitrarily assigned to solutions.

The description of oxygen diffusion modeling (GRE, 2014f) is cryptic and insufficient to evaluate. The oxygen consumption rates are reportedly taken from the geochemical modeling and are representative of the oxygen consumed by ARD reactions in the LV material. Based on that analysis, GRE derived an oxygen half-life of 700 days. The results of the oxygen consumption and oxygen diffusion modeling reportedly (GRE, 2014f) showed that oxygen penetration is limited to the uppermost 0.5 meter of the mine waste. However, GRE (2014f Figure 10) shows oxygen concentrations decreasing downward through 0.5 m of topsoil overlying backfill and arrows in the backfill point upward. Additionally, GRE (2014f) states that similar results were obtained for the Arshak pit bottom. Topsoil and fractured rock on the pit bottom have entirely different material properties. GRE (2014f) then states that the total depth of oxygen penetration is assumed to be 1.5 meters, consistent with results of analysis for the BRSF. This explanation is incomprehensible. The BRSF configuration is the same as the pit backfill, with soil overlying waste rock.

The procedures and resulting problems with the initial solutions are similar to the above description for the runoff modeling of the pits, e.g., use of ARD-74C HC week 10 test solution for the Arshak seepage and charge balancing with fluoride and sodium. After charge balancing each of the weekly HC solutions for the backfill, the text states the solutions were passed through the 1.5-meter-thick oxygenated zone of the waste rock (in contrast to the 0.5 m previously stated) and that in the LV rock, the oxygenated equilibrium resulted in the production of ARD. GRE also stated that kinetic analysis was not utilized due to the long travel time of water within the unsaturated pit backfill. These statements indicate that the solutions were equilibrium reacted with a set of minerals representing the waste rock under oxygenated conditions and, that phases were permitted to precipitate. Then, according to GRE (2014f), an anoxic equilibrium phase analysis was performed to simulate the de-oxygenated conditions deep within the pit backfill. Presumably this statement means that a different set of saturation indices were calculated, and phases were selected to precipitate and/or permitted to dissolve. The step at which an average solution was calculated is not clear. For the Arshak pit, GRE (2014f) states that the ARD-74C HC week 10 test solution was reacted with LV waste rock for 20 weeks using PHREEQC's kinetic function. Then an anoxic phase equilibrium analysis was performed, as for the backfill solution, to simulate the de-oxygenated conditions deep below the Arshak pit bottom.

The final simulated water qualities of Arshak seepage and Tigranes-Artavasdes seepage are presented (GRE, 2014f Table 3) with a statement that the water quality is consistent with water samples representing long-term ARD reactions that are occurring in unmitigated LV waste piles located in Sites 13 and 27. The simulated solutions are very different from each other, and pH of the solutions are in the range of the pH of Site 27 leachate. Otherwise, little similarity is observed. Especially noteworthy is the iron concentration of 3.2 mg/L in the Site 27 leachate (ESIA Appendix 4.6.2 Table/Appendix F-1), compared to simulated total iron concentrations (ferric and ferrous) of approximately $3.05x10^{-5}$ mg/L and $5x10^{-3}$ mg/L for Arshak and Tigranes-Artavasdes seepage, respectively. The simulated solutions have essentially no copper; silicon was not simulated, and nitrogen was not simulated for the Arshak seepage. The simulated results for iron and copper are indicative of the same suspect phases that were specified to precipitate as for the runoff modeling (Appendix C of this report shows the phases that were specified in the modeling).

2.1.3.3.3 Backfilled Erato Seepage

The geochemical modeling of the water quality of post-closure seepage from the partially-backfilled Erato pit (Golder, 2014e) is generally well done with respect to current, accepted methods, the procedures are well documented, and a range of results was produced based on uncertainty of inputs. However, there are some important concerns. The modeling uses the results of the Erato post-closure pit water balance (Golder, 2014c). Golder (2014e) include the following conflicting statements:

- Seasonal fluctuations in the inflows and outflows of the pit result in a shallow, strongly seasonally-dependent (ephemeral) water body within the backfill;
- Evaporation losses in the water balance model include both evaporation from the pit water surface and from the saturated backfill to a depth of 1 meter; and
- Water levels in the backfill are below the top of the backfill at all times.

More importantly, the water balance reported in Golder (2014c) does not incorporate (does not mention) backfill. Golder states an assumption for the water quality modeling that the pit will be backfilled to the level required to contain the water body. Unclear is how a water balance model based on a seasonal pit lake (with water surface evaporation) with no backfill was adapted for use with backfill. Golder (2014e) correctly states that the assumption of 40% of precipitation on the pit walls reporting to the pit bottom is non-conservative; yet, GRE (2014e) used that assumption to remain consistent with other ESIA studies.

Golder (2014e) subdivided the LV for modeling into two categories on the basis of paste pH and sulfide sulfur into Lower Volcanics – Pyrite and Lower Volcanics – Other. The Lower Volcanics – Pyrite is distinguished by high pyrite concentrations (> 1 wt. % sulfide sulfur and paste pH <4), acidic HC leachates, and considerable metals leaching. The Lower Volcanics – Other has more alunite and less pyrite, yielding HC leachate pH values ranging from 4.5 to 6.5. This subdivision is a good first step toward developing geochemical units, but HC and bucket test results for the LV (see Section 2.1.1.2.3.2 of this report), as well as the large range in pyritic sulfur (up to 9.5%), indicate further subdivision may be warranted (for the geochemical modeling also).

Table 1 of the Golder (2014e) report showing PHREEQC input parameters includes a long list of minerals as potential phases that could be specified to precipitate in the modeling (if supersaturated). With the exception of mentioning barite (Ba control) and schwertmannite (Fe control) in the results section of the report, the specific mineral phase controls on the chemistry of the solutions were not provided. In this context, the resultant range of iron concentrations is low, with a mean of 0.003 mg/L and a maximum of 0.3 mg/L (cf., iron concentration of 3.2 mg/L in the Site 27 leachate [(ESIA Appendix 4.6.2 Table F-1]). Silicon was omitted in the modeling. Otherwise, the simulated pH and concentration ranges encompass the observed pH and concentrations in the Sites 13 and 27 waste leachates and mine portal drainage.

2.1.3.3.4 Solute Transport Simulations

Solute transport calculations were performed with a spreadsheet (analytical) model for a 1,000-year time frame following closure based on particle paths determined from the simplistic regional groundwater flow model. Concentrations in surface water were calculated based on mixing of groundwater with the receiving waters. Use of a spreadsheet model to evaluate potential impacts is a screening level approach that is not appropriate for a project of this scope in such an environmentally-sensitive area. Given the complex geology of the GSA (faults, fractures, stratified rocks), a spreadsheet model cannot accurately represent the physical system (cf., INAP, 2009). Instead, solute transport simulation should have been integrated into and predicted using the regional numerical groundwater flow model.

Golder (2014d) states that the groundwater flow model represents a simplification of the complex geology (intensely-faulted rocks) surrounding the pits. Due to the uncertainty introduced by the simplification of the geology, a local area impacts scenario was developed based on the assumption that 100% of the mining influenced groundwater migrates to perennial springs in close proximity to the pits. This scenario is based on simple mixing/dilution of the solute mass released from the source areas with groundwater recharge estimated for each assumed local catchment contributing to a set of springs.

The text (Golder, 2014d) states that the understanding of potential solute migration pathways from the pit areas is substantially based on groundwater flow modeling (Golder, 2014a). The text states that five flow paths are defined which represent the majority of the infiltration from the closed pits as seen by the concentration in flow lines for these pathways. This statement gives a lot of weight to the model-determined pathways, yet for the spreadsheet model, assumptions are made about depths of transport pathways that are completely different than the groundwater flow model particle paths. The flow model advective transport times are voided and replaced with arbitrary, up to an order-of-magnitude shorter travel times to receptors and are justified on the basis of conservatism. The regional groundwater flow model cannot be both correct and incorrect. This approach is not good science. It is obvious that Golder does not have confidence in the groundwater flow model. Neither the spreadsheet model nor the existing groundwater flow model is suitable for the transport calculations. The regional model should be revised (see Section 2.1.2.5) and used for solute transport.

Elaborate schemes were devised for partitioning fluxes from the base and walls of each pit sub-area to various solute transport pathways and determining separate source concentrations for the pathways, based partly on division of the area around Amulsar Mountain into multiple sub-areas. The same approach was used for the local area scenario.

The spreadsheet calculations of solute transport and the local impacts scenario based on mixing are not conservative, with source concentrations determined by geochemical modeling that are too low. Furthermore, loading rates to groundwater are underestimated due to seepage rates from the pits that are too low, and the predicted concentrations in the spreadsheet model do not include the effects of the BRSF and HLF. With no alkalinity in the volcanic rocks, the acidic seepage water will leach additional metals on its pathways through the subsurface and exacerbate the ARD impacts.

2.1.3.4 Potential Impacts due to Initial Mine Construction Work

As part of the assessment of potential impacts of initial Amulsar Mine construction activities on water resources, ELARD-TRC Team reviewed monitoring data obtained by the "Environmental Monitoring and Information Center" of the MNP (SNCO, 2019).

Pursuant to a Lydian press release (Appendix C of this report), groundbreaking of the Mine occurred on August 19, 2016. However, there was no information available as to the schedule or sequence of the initial construction activities or when these activities were suspended.

SNCO has been monitoring the surface water quality at three observation points in the region of the Amulsar Mountain since 2006. The monitoring frequency varied from monthly to quarterly. The last monitoring event was in November 2018. The monitoring points are located on the Arpa River, Vorotan River, and Kechut reservoir. The Arpa River location is closest to the Amulsar and downgradient of the mine areas where most of the initial construction work occurred.

The SNCO groundwater monitoring program includes annual monitoring of the discharge at four springs, including:

- Spring 529 located near Gorhayq village (Syuniq Province) and Spandaryan reservoir
- Spring 650 located in Jermuk City (Vayoc Dzor Province)
- Spring 2048 located in Jermuk City (Vayoc Dzor Province)
- Spring 2060 located in Ketchut village (Vayoc Dzor Province)

SNCO has also been monitoring the groundwater quality of Spring 529 discharge semiannually since June 2015. The last monitoring event was in November 2018.

The provided data package did not include descriptions of sampling methodologies or analytical methods or standards. Moreover, no other information or details were provided about the monitoring points or about human or other activities or climatic conditions near the monitoring points. Therefore, only a preliminary comparative screening of data collected before and after the start of initial construction activities at the Amulsar Mine was conducted.

A review of the data (SNCO, 2019) indicates that there was an apparent increase in the concentration of nitrate in a water sample collected from Spring 529 in October 2016 (within two months post groundbreaking). However, the concentrations seemed to diminish rapidly by early 2017 but seemed to rebound by November 2018. No similar trend to that observed for nitrate could be discerned in other constituents or in the discharge rate of Spring 529. Sulfate concentrations exhibited a spike in June 2016 before the mine groundbreaking event, followed by a rapid and sustained decrease in concentrations. The annual average discharge data for Spring 529 exhibit a sustained decreasing trend since monitoring began in 2015.

The water quality data for Spring 529 were also compared to data obtained for the three surface water monitoring points on the Arpa River, Vorotan River, and Kechut reservoir. The comparison did not show any corresponding trend to that of nitrate at Spring 529, including in the Arpa River. These data suggest the nitrate trend at Spring 529 are localized and transient.

Given the absence of a corresponding trend in other constituents and in the discharge rate at Spring 529, and the paucity of data and details, the transient and localized nitrate trend cannot be attributed with a reasonable degree of scientific certainty to the initial mine construction activities. Accordingly, no discernable impacts to surface water or groundwater due to initial mine construction activities could be inferred from the SNCO (2019) data.

2.1.4 Project Water Balance

Golder (2018) presents analyses that utilize modeling to update the SWWB for the Project. Golder (2018) includes updates to calculations presented in the earlier SWWB (Golder, 2016a) based on review by GRE as well as based on design modifications and changes in production schedule and evolution of facility footprints. Some of the current assumptions are based on agreement between Golder and GRE.

The objective of the SWWB model is to estimate the volume of excess water generated and process make-up water demand over the construction period and operational life of the mine (LoM). Based on the model results, storm and process ponds and pipelines were sized for each of the major Project facilities (BRSF, HLF, and mine pits). The SWWB will be continually updated.

The current SWWB is based on historical climate data from both the Jermuk and Vorotan weather stations. Jermuk climate data were used for evaluations below 2,200 m (HLF).

The SWWB is based on a wide range of uncertainty evaluated with stochastic simulations of climate variability using the GoldSim software. Peak 24-hour events and maximum annual precipitation depths from the continuous time series produced by the simulator for the LoM were used to evaluate storage requirements that include the 100-year, 24-hour precipitation event. Minimum precipitation depths from the continuous time series were used to evaluate potential make-up water requirements.

The probabilistic models of weather for each station are a good basis for design. However, the source of the percentages of snow melting when temperatures are below freezing (95% for above 2,200 m and 92% for below 2,200 m) in the snow accumulation calculation are not provided. Likewise, references for sublimation of 10% of snowpack below 2,200 m and 20% above 2,200 m are not provided. No justification is given for the choice of melting coefficient (2.74 mm/°C/day) from the referenced range (1.6 to 6.0 mm/°C/day).

The water balances illustrated and outlined for each facility are logical. However, some parameters are questionable and/or have very high uncertainty, such as the annual volume of groundwater reporting to the pits. Also, for pit backfill and the BRSF, a soil evapotranspiration parameter was applied. If this parameter is derived from (GRE, 2014b and GRE, 2014c), evapotranspiration is much too high and infiltration and runoff are correspondingly low. Furthermore, the illustration for the BRSF indicates that a pan factor and a soil moisture adjustment were used to calculate evaporation of surface water on the backfill and BRSF. This calculation is not explained, and it is not clear whether there is a soil cover on the materials.

The results for the 95% probability of exceedance suggest sufficient capacities are calculated for pit pumping and pond sizing. Section 9.0 of the Golder report correctly states there is uncertainty in some of the water balance inputs such as evaporation rates from different surfaces, runoff coefficients, and infiltration rates. Addressing the issues raised in the previous paragraphs can reduce some uncertainty. Pond volumes are based on the 100-year, 24-hour precipitation event, which is consistent with International Finance Corporation (IFC) performance standards (PS).

Noteworthy is that the water balance conceptualizations for the pits and BRSF are more realistic and meaningful in the SWWB (Golder, 2018) than those presented in the Pit Seepage and BRSF Runoff and Seepage Sub-Models (GRE, 2014a/2014b/2014c).

2.1.5 Mitigation Measures

ESIA Section 6.0 presents an assessment of the sources of environmental impacts related to the Mine infrastructure and activities during construction, operations, and closure in the context of the regulatory framework, Lydian policy framework, and Project-specific criteria. The main sources of potential impacts to surface water and groundwater are the BRSF, the HLF, the Mine pits, and all infrastructure for collecting, channeling, impounding, and treating contact water. A mitigation measure is defined in the ESIA as the engineering design to reduce impacts to acceptable levels.

Generally, the design concepts used in the Amulsar ESIA/EIA for development of mitigation measures are reasonable and appropriate (e.g., low permeability liners, encapsulation, capping, drainage, and leachate treatment). However, a number of the measures and plans, are partial, not-sufficiently protective, and/or unreliable with a high degree of uncertainty, particularly due to deficient and questionable data, models, model simulations, design bases, and/or assessment.

2.1.5.1 Mine Pits

The mitigation measures that will be implemented for the mine pits are partial backfilling and emplacement of an evapotranspiration (ET) soil cover on backfill. Non-PAG VC waste rock is intended for backfilling the Erato pit, which will not be covered with an ET medium, and is expected to seasonally accumulate runoff that would develop a pit lake without backfill. The base of the Tigranes-Artavasdes pit is expected to be below groundwater levels, which would result in the development of a permanent pit lake without emplacement of backfill. PAG waste rock will be placed in this pit and overlain by an ET cover.

Backfilling pits that accumulate runoff and groundwater prevents evapoconcentration of dissolved constituents. Pit lakes can develop anoxic conditions in the deep water, especially a deep pit lake as expected for the western end of the Tigranes-Artavasdes pit. Anoxic conditions increase metals solubility, and this anoxic, evapoconcentrated water would seep to groundwater. The backfilling, therefore, mitigates the negative effects of pit seepage to groundwater. Backfilling also mitigates impacts to fowl and fauna.

The ET soil cover on the Tigranes-Artavasdes backfill limits infiltration of precipitation and snowmelt. The cover will also limit oxygen ingress to the LVA PAG backfill. The cover, therefore, mitigates generation of ARD from backfill and seepage of ARD-impacted water to groundwater. Infiltration of precipitation during prolonged wet conditions and snowmelt will occur, however, carrying oxygenated water into the pit backfill, and potentially generating ARD.

Appropriate mitigation measures are planned for the Tigranes-Artavasdes pit. Considering the potential that some of the non-PAG VC rock intended for backfilling the Erato pit could also be acid generating (see Section 2.1.1.2.3.2), an ET cover would also be appropriate. The Arshak pit will not be backfilled and will seasonally accumulate runoff in the base of the pit. Backfilling the Arshak pit would mitigate seepage of evapoconcentrated seasonal lake water.

Only complete backfilling and covering would be better options. Noteworthy is the unavoidable accumulation of runoff water in the backfill of the partially backfilled pits. This potentially acidic runoff water is oxygenated and could react with backfill in the base of the pits, leaching metals and oxidizing sulfides. The Arshak runoff accumulation is also in contact with the backfill. Anoxic conditions could also develop in saturated backfill due to depletion of oxygen by reaction with the backfill and microbial activity, increasing solubility of the metals in the seepage to groundwater. Any infiltration through backfill could contribute to the load. The seasonal Arshak pit lake will also contribute seepage to groundwater.

There is clearly potential for contamination of groundwater by ARD-impacted pit seepage water. There are no contingency plans to mitigate groundwater contamination originating during operation and post closure from the pits beyond monitoring, for which no details are provided.

2.1.5.2 BRSF

The BRSF mitigation measures include:

- Encapsulation of LVA PAG waste rock in non-PAG VC waste rock (post closure);
- An ET cover (post closure);
- A non-PAG VC rock drainage layer beneath the PAG rock;
- Compacted native clayey soil or constructed clay liner beneath the non-PAG rock drainage layer;
- Subgrade drains with piping in perennial stream channels where groundwater emerges beneath the BRSF;'
- A toe pond to hold contact water collected by the subgrade drains; and
- Runoff diversion channels.

These planned mitigation measures for the BRSF are generally appropriate. Note that neither of the provided versions of the ARD Management Plan (Geoteam, 2016c; GRE, 2017) discusses emplacement of soil liner fill material in areas where the subgrade native clayey soil does not meet the specifications for a soil liner. The constructed clay liner is mentioned in GRE (2014a), with details provided in Golder (2017).

According to Geoteam (2015 Section 3.2.3), the BRSF will be founded on a low permeability liner, which will be comprised of native clayey soils (subgrade) with a maximum hydraulic conductivity of $1x10^{-6}$ cm/sec. Geoteam (2015 Section 3.4) specifies a thickness of 0.3 m and a hydraulic conductivity of $1x10^{-5}$ cm/sec as the design criteria (vs. $1x10^{-6}$ cm/sec in Golder (2015 Section 3.2.3) and in Golder (2017)). Geoteam (2015 Section 3.4) further states that based on the modeling results "*the Project is not required to conduct extensive confirmatory hydraulic conductivity testing in order to ensure that the $1x10^{-5}$ cm/sec target is achieved*." The clay liner would be placed in 0.15 lifts and be compacted by vehicle traffic. In areas, of exposed scoria and basalt, a compacted clay liner will be constructed using borrow material from local areas.

The ET soil cover on the BRSF limits infiltration of precipitation and snowmelt. The cover will also limit oxygen ingress to the waste rock pile. The cover, therefore, mitigates generation of ARD from PAG waste rock and potential seepage of ARD-impacted water to groundwater. However, infiltration of precipitation during prolonged wet conditions and snowmelt will occur, carrying oxygenated water into the BRSF rock pile.

The intent of the non-PAG layer of waste rock under the soil cover and overlying the LVA PAG waste rock is to deflect infiltration water laterally at a presumed permeability contrast, preventing infiltration into the PAG waste rock. The design is conceptually appealing but deceiving. The LVA PAG waste rock is not an impermeable pile of fat clay. The LVA waste rock will consist of blocks, chunks, and pieces of rock with a range of grain sizes. Pore space among these various rock particles will permit infiltration. Consequently, some ARD will occur further adding to the mass flux reporting to the PTS.

The design concept of using non-PAG drainage layer at the base of the waste rock pile and an underlying low permeability clay liner to deflect seepage through the BRSF to the subgrade drains and mitigate infiltration to groundwater is adequate. However, the key liner design criteria are unreliable and raise concerns about the long term integrity, performance, and protectiveness of the liner including:

- The effectiveness of vehicle traffic in compacting native soil to develop a uniformly low permeability liner and the plasticity and homogeneity of the native soil across the BRSF area. Appropriate soil compaction equipment should be used.
- The small thickness of 0.3 m[15] and the relatively high hydraulic conductivity of $1x10^{-5}$ cm/sec (vs.$1x10^{-6}$ cm/sec specified in Golder (2107) and Geoteam (2015 Section 3.2.3)), particularly given the questionable modeling results and variability in subgrade conditions.
- The high degree of uncertainty associated with limiting the confirmatory hydraulic testing, particularly given the variability in subgrade conditions.

The toe pond size is based on the 100-year, 24-hour precipitation event consistent with IFC PS.

2.1.5.3 HLF

The mitigation measures included in the design of the HLF are generally appropriate. The design includes a composite liner system consisting of geomembrane underlain by compacted low permeability soil or geosynthetic clay liner in the steep terrain. The pregnant leach solution

[15] Typical design criteria for constructed clay liners in the USA are: thickness of 2 feet to 3 feet (0.6 m to 1 m) and hydraulic conductivity of $1x10^{-7}$ cm/sec to $1x10^{-6}$ cm/sec.

(PLS) will percolate through the ore to a drainage collection system above the liner consisting of perforated drain pipes embedded in a durable granular medium. The PLS will drain laterally from the HLP through transfer pipes to the process pond.

Diversion embankments and channels will be constructed upslope of the various HLF phases to divert storm and snowmelt runoff away from the pad and collection ponds. Underdrains consisting of trenches with pipes will be constructed in existing drainages and seeps within the leach pad and collection pond footprints for discharge to a collection sump, where the discharge water quality will be monitored for release or use as process water. The leach pad will have a toe berm and perimeter berms to prevent applied solution and rainfall/snowmelt water within the pad from overflowing the pad. The solution and storm flows will be routed to the process pond.

The HLF collection ponds include the process pond and storm water ponds to contain overflow from the process pond. The collection ponds were sized according to Project design criteria using the results of the HLF water balance calculations for wet year climatic conditions. Pond volumes are based on the 100-year, 24-hour precipitation event consistent with IFC criteria.

The process pond will have a composite double-geomembrane liner system underlain by a compacted low permeability soil liner. A leak collection and recovery system (LCRS) layer will separate the two geomembranes. The storm water ponds will have a composite liner consisting of geomembrane underlain by compacted low permeability soil. The collection ponds will have floating "bird balls" to prevent birds from contacting cyanide-bearing solutions.

Closure measures include an ET soil cover on the HLF to limit infiltration of precipitation and snowmelt. The cover will also limit oxygen ingress to the spent ore.

A fence with locking gates will be constructed around the perimeter of the HLP. This fence will bar entrance to livestock and wildlife, as well as unauthorized human access.

2.1.5.4 Contact Water Treatment Systems

Treatment of the contact water discharged from the mine operations is important to ensure that surface water quality is not impacted above applicable Armenian water quality standards. The ESIA focuses on and proposes PTS for the Mine contact water. Two PTS's are proposed - one for the heap pile leachate after mine closure and the second for the BRSF leachate (i.e., ARD) both during and after closure of mine operation. The heap pile leachate treatment system is addressed in a separate section, while the discussion below focuses on the PTS for the BRSF.

The ESIA (Section 6.10, page 22) and ARD Management Plan – V. 3 (Geoteam, 2016c Section 1.1 Commitments) indicate that if treatment trials indicate that a PTS will not meet the discharge criteria (MAC II standards) then a conventional packaged active water treatment system will be used. There are no descriptions of the decision-making process or details about the active treatment processes or requirements. Noteworthy, however, is that the commitments made in the ARD Management Plan – V. 3 (Geoteam, 2016) including the commitment to use active treatment in case of PTS inability to meet MAC II Standards, have been omitted in the updated ARD Management Plan – V. 4 (GRE, 2017). Therefore, this option cannot be assessed.

Furthermore, Lydian during the March 28, 2019 presentation and the June 27, 2019 conference call indicated that it will adopt an adaptive management approach for the mitigation and treatment of the Amulsar Mine impacts on water resources. However, Lydian provided no details or protocols for this approach. Therefore, the adaptive management approach cannot be assessed.

2.1.5.4.1 ARD - BRSF

2.1.5.4.1.1 Overview

The PTS for the BRSF leachate is described in Appendix 8.19 of the ESIA (GRE, 2017) and in a design basis memorandum (Sovereign, 2015). The PTS will treat water from the BRSF and excess water from the HLF operation during the time the mine is active, and will treat the BRSF leachate after the mine closes. The water is planned to be collected in pond PD-8 and then sent to the PTS. Sovereign (2015) shows the PTS will consist of the following units:

- Pond PD-8;
- Nitrate Reducing Biochemical Reactor (BCR);
- Aerobic Polishing Wetland (APW) No. 1;
- Sulfate Reducing BCR;
- Sulfide Scrubbing Unit;
- APW No. 2;
- Manganese Removal Beds (MRB); and
- A discharge pipe to the Arpa River tributary located downgradient from HLF ponds.

GRE (2017) has a similar sequence, with the exception that the first aerobic polishing unit has been replaced by an anoxic limestone drain.

The treatment system is based on projected water quality coming primarily from the BRSF toe pond, which is transferred to PD-8. The focus of the ESIA discussion of the PTS is on ARD from the BRSF, with less emphasis on the treatment of water coming from the mine pits to PD-8 and on nitrate and ammonia from the blasting residues on the rock. The nitrate reducing bioreactor is obviously designed to remove nitrate from the blasting operation, but there is little discussion on the incoming nitrate concentrations, and no discussion of ammonia. The incoming water is inexplicably projected to have low iron and aluminum concentrations. This is a key and questionable assumption given that there will be ARD in the BRSF and the pits' water going to the HLF (GRE, 2014d), as will be discussed later.

There are three major concerns with the proposed PTS design bases as discussed below:

1. The system design using a PTS has been selected too early in the process and does not allow the flexibility needed to deal with such a complex water system. The design is based on simulated water quality that may or may not be valid. If the simulated water quality is not valid, then the system will most likely fail and not achieve the treatment objectives.
2. The water quality modeling has significant discrepancies that make the modeling results highly uncertain and raise concerns about the ability of PTS to meet treatment objectives.
3. Ammonia in the wastewater will most likely be present at concentrations well in excess of the discharge criterion, but the treatment process for the ammonia is not discussed except in brief comments. Nitrate treatment is discussed in a little more detail, but is not given the focus that it should have and the nitrate concentrations appear to have been underestimated. Nitrate and ammonia are likely to be major contaminants that require

treatment while the mine is operating along with the products of ARD. The system as designed may not be able to achieve the treatment criteria for either nitrate or ammonia.

2.1.5.4.1.2 PTS Approach

The approach has been to develop a model of the water requiring treatment, select and design a system to treat that water, and then build the treatment system early in the life of the mine. The emphasis has been on a passive biological system rather than active system with no discussion of why a passive system was selected. As shown in the Table 2.1.1 below, the GARD Guide (INAP, 2009; Table 7-1) suggests that a passive system is most appropriate for closure and post-closure phases, while an active system is more appropriate for operational phases.

Table 2.1.1: Qualitative Comparison of Different Categories of Treatment (INAP, 2009; Table 7.1)

Feature/ Characteristic	Active Treatment	Passive Treatment	In Situ Treatment
1. Application to phase of mining	Most appropriate to exploration and operational phases because it requires active control and management. Closure and post-closure applications mainly associated with large flows	Most attractive to the closure and post-closure phases, because it requires only intermittent supervision, maintenance, and monitoring of self-sustaining properties.	Appropriate to the exploration and operational phases because it requires ongoing operation and maintenance

However, in contrast with INAP (2009) recommendations for using an active treatment system during mine operations, the ARD Management Plan for the Amulsar Mine (GRE, 2017) considers only a PTS for the BRSF during both operational and post-closure phases. GRE (2017) focused on the water quality and volume during the post closure phase and did not elaborate the rationale or feasibility for using a passive system during mine operation.

The use of a passive (vs. active) treatment system was decided early in the design of the mine, as illustrated by Sovereign (2015). There is no indication that any review has been given since then as to whether an active system should be used (except in response to the comments by Bronozian as discussed below) despite the update of the site-wide water balance (Golder, 2018).

Further, the selected PTS depends on very low iron and aluminum concentrations in the incoming water, as projected in the geochemical model. The major concern is that the whole system depends on the accuracy of the initial water model, both in terms of volumes and water quality, and on the biological systems behaving as predicted. There are many places where this model could be off, both in terms of flow and more importantly in terms of water quality. The amount of water seeping through the LV rock in the BRSF and the pits and generating ARD (including iron, aluminum, sulfate, acidity) could be off as noted in Golder (2018), and the modeling of the water quality could be off (refer to Sections 2.1.1.2; 2.1.2; and 2.1.3 of this report). To select a PTS that requires low metals content for mine water coming from an area of known ARD, with very little flexibility once the system is constructed, seems imprudent. The ARD in the area has high aluminum concentrations, and ARD is known to have iron concentrations as seen in the humidity cell leachates and as discussed in Sections 2.1.1.2 and 2.1.3 of this report. To design and implement the system based on incoming water having low iron and aluminum concentrations requires a high degree of certainty in the accuracy of the water quantity and quality, which the current models do not have. Even if the water quality modeling is correct (and even if concerns noted below are nonexistent), changes in mining operations or projections thereof may alter the inputs to the model, and hence the projected metals concentrations. At this stage, it is prudent for the design to be flexible to account for uncertainties in the water quality modeling projections and results.

Even if the model provides a good projection of the incoming water quality, there is no certainty that the proposed system would work. Biological systems are subject to numerous influences that can prevent or disrupt operation, and the system may not work as designed. Bench scale[16] and field scale pilot treatability studies are needed before the design is finalized. The success of studies will require good understanding and accurate representation of the incoming water quality, and of the range of concentrations of the key parameters in the incoming water. The water quality of the incoming water is subject to too many influences to be accurately modeled ahead of time. Rather, the water quality needs to be determined after the mine is in operation and the water quality can be directly measured. Moreover, the actual time as to when this PTS system should be operational may occur earlier than the timing (*i.e.,* Year 4/5) projected by the site-wide water balance calculations (Golder, 2018). Therefore, a flexible (*i.e.,* active) water treatment system may need to be considered for treating any discharged water prior to developing the final system.

The GARD Guide (INAP, 2009) similarly states in Section 7.3 (Mine Drainage Treatment):

> The approach adopted for mine drainage treatment will be influenced by a number of considerations related to the following: …Different stages of mining and how the mine water system and water balance will change over the life of the mine. A mine drainage treatment facility must have flexibility to deal with increasing and decreasing water flows, changing water qualities, and regulatory requirements. This may dictate phased implementation and modular design and construction of a treatment facility.

As noted above, the ESIA (Golder, 2016) and older ARD Management Plan – V.3 (Geoteam, 2016c) states that if treatment trials indicate that a PTS will not meet the discharge criteria, an active water treatment system will be used. However, the bench scale treatability tests currently being conducted are not aimed at evaluating the PTS performance under varying conditions or determining under what conditions the PTS will fail. Instead, the bench scale tests are focused on a specific set of treatment processes and on demonstrating that the PTS is successful for a very limited set of input water quality conditions. If the tested water quality conditions are not representative of the actual water quality from the Site throughout both the active phase of mine operation and after the mine closes, then the testing does not address the question of whether an active or passive system should be used.

Wardell Armstrong (2017) provided responses to comments provided by Buka (2017a/b), Clear Coast (2017), Blue Minerals (2107), and Blue Minerals *et al.* (2018) about the Mine's water quality and treatment issues. A typical response is given below (Wardell Armstrong, 2017 page 8):

> 3.6.3 Passive Water Treatment
> Passive treatment of mine-impacted water is a standard method for treating and managing water quality concerns from metals mines (INAP, 2009).

[16] A limited laboratory bench scale testing by Lydian is ongoing.

Passive treatment is an effective method to mitigate mild ARD and drain down from a spent HLF and rapidly becoming the industry-standard for all but the most severe ARD. Please see (A.M. Moderski, 2013), [(INAP, 2009), Section 7.5.2.]. Passive treatment was successfully applied, for example, at the Santa Fe Mine in Nevada, USA to treat HLF drain-down (R. Cellan, 1997). Predictions performed to-date and reviewed by IESC confirm that the predicted ARD and HLF drain down fall well within the range of acceptable chemistry that is treatable with passive treatment technology.

The passive treatment system outlined in the ARD Management Plan is consistent with successful designs world-wide. Furthermore, a detailed programme of studies will confirm the efficacy of the design of the passive treatment system. The treatment system will be assessed using laboratory and field scale trials, which have been discussed with, and reviewed by, independent consultants. The testing will be completed by August 2018.

The above response along with the omission of the commitment to use active treatment in the updated ARD Management Plan (GRE, 2017) indicate that active treatment is not seriously considered. The GARD Guide (INAP, 2009 Table 7-1) specifically indicates (Table 2.1.1 above) that passive treatment systems can be used for ARD after mine closure, but that an active system is most appropriate during mine operations. The inference in Wardell Armstrong (2017) responses that the GARD Guide affirms that passive treatment is effective at all times in the mine operation is untenable and is contrary to INAP (2009 Table 7-1) recommendations. Passive treatment can work and has worked in a number of cases, and it may be appropriate for the Amulsar Mine. But to select a PTS for an active mine, and even for post-closure strictly based on questionable modeling data (see discussion below) without a definitive analysis and actual measurements of the influent water quality is incorrect. It is essential at this point to have a plan for collecting representative and necessary data and treatability testing to design treatment systems for operation and post-closure phases. Such activities should include pilot scale tests to assess the effectiveness of the cap on the BRSF for minimizing ARD generation, and the dynamics of acid generation, metals leaching, and nitrate and ammonia leaching from the rock after blasting.

2.1.5.4.1.3 Geochemical Modeling

The ARD Management Plan (GRE, 2017; v.4) states that "*Geochemical modelling has predicted that the mine contact water quality that* ***[sic]*** *can be treated with passive treatment methods. Table 14 shows the anticipated average water quality post-closure.*" Table **2.1.2** below presents excerpts of Table 14 (GRE, 2017):

Table 2.1.2: Projected PTS Influent water quality (GRE, 2017; Table 14)

Quality Indicators	Unit	Detention Pond (PD-8)
pH		3.92
Acidity	mg/L $CaCO_3$	157.2
Aluminum	mg/L	27.2
Calcium	mg/L	12.5
Chloride	mg/L	0.215
Iron, total	mg/L	5.66E-07
Magnesium	mg/L	5.11
Manganese	mg/L	0.0016
Nitrate	mg/L N	2.35
Potassium	mg/L	6.39
Sulfate	mg/L	97.3

There are discrepancies between modeled water quality shown in Table **2.1.2** and the water quality model given by GRE (2017) and that given by Sovereign (2015) as noted below.

A. *Iron concentrations are too low – key parameter for system as designed*

The treatment approach adopted is described in the GARD Guide (INAP, 2009) and is for influent water with low metals concentration, namely iron (Fe) < 2 mg/L and aluminum (Al) < 2 mg/L and dissolved oxygen (DO) <1 mg/L. Higher Fe and Al concentrations can cause problems in some systems as the metals precipitate and form solids that can clog the treatment system. Water coming from pyrite oxidation can have elevated concentrations of iron and aluminum (if the acid water passes through aluminum-bearing solids). The water in the humidity cells have maximum iron concentrations of approximately 125 mg/L and aluminum concentrations of 85 mg/L (GRE 2014d). Thus, the influent water of the PTS needs to have significantly lower metal concentrations than those concentrations in order to justify the proposed low metal PTS layout, and the current design may not be able to treat the ARD generated at the Site.

The projected iron concentration in Table **2.1.2** ($5.66x10^{-7}$ mg/L) for PD-8 water, which is presumably coming from an ARD process, is unrealistically low as summarized below:

- This iron concentration in the modeled PD-8 water is significantly lower than iron concentrations in the Amulsar groundwater and surface water and even rain water, including water not affected by ARD, which range between approximately 0.001 and 300 mg/L (Lydian, 2018; Golder, 2019).
- GRE (2017) suggested that iron is in the ferric oxidation state, with the concentration controlled by Schwertmannite, a ferric hydroxysulfate commonly found in ARD water, along with Jarosite. Schwertmannite is only stable under low pH conditions and will slowly transform to goethite under acid conditions (Vithana *et al.,* 2015). Studies on Schwertmannite solubility in actual ARD have found iron concentrations of approximately 10^{-5} to 10^{-6} M at pH values between 3 and 4 (Yu *et al.,* 1999). Vithana *et al*. (2015) give ferric iron (Fe^{3+}) solubility lines for Schwertmannite[17], which give iron concentrations of 10^{-5} to 10^{-8} M at pH values between 3 and 4. These correlate to iron concentrations of $5x10^{-1}$ to $5x10^{-4}$ mg/L, approximately 3 to 6 orders of magnitude higher than the predicted iron concentration in the PD-8 water. Measured iron concentrations in ARD water in contact with Schwertmannite are at the higher end of the solubility calculations, suggesting that the projected values for PD-8 are underestimated by a factor of 10^6.
- Snoeyink and Jenkins (1980) give an average iron concentration of around 0.05 mg/L for iron in terrestrial waters (covering a wide range of Eh and pH conditions) with values ranging up to around 5 to 10 mg/L, or five to seven orders of magnitude higher than the water coming from pyrite oxidation in the site water.
- The GRE (2017) analysis does not include iron and aluminum concentrations typical of ARD, which can contain much higher iron concentrations. The GARD Guide (INAP, 2009) states that iron concentrations in ARD can range from 1,000s to 10,000s mg/L.

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[17] $[Fe^{3+}]$ = -2.582 pH + 2.996 and -2.582 pH + 1.946 (Vithana *et al*., 2015)

- Sovereign (2015) recognized this discrepancy in the water quality projection and modified the PTS influent water quality shown in Table **2.1.2** (GRE, 2017; Table 14) by increasing the iron concentration to be more realistic and representative of ARD, albeit still lower than expected levels for ARD and in some Amulsar groundwater samples (Golder, 2019).
- GRE (2017) assumed the iron to be in the ferric oxidation state. However, pyrite oxidation first generates iron in the ferrous oxidation state[18], which is much more soluble at low pH than is ferric iron. Ferrous iron will oxidize to ferric iron and after oxidation contributes to the acidity of ARD. But, it has to oxidize first. Under conditions of somewhat limited oxygen supply, pyrite will oxidize to yield a low pH water with high ferrous iron content. Once this water encounters more oxic conditions, iron will oxidize and precipitate as Schwertmannite, Jarosite, or ferrihydrite to form the "yellow boy" seen in the drainage from many old mines. If there is pyrite oxidation, the question of where the ferrous iron oxidizes becomes very important in determining how to treat the ARD.

The discrepancy and high uncertainty in iron concentrations does not give confidence in the modeled water quality and raises concerns about the certainty and reliability of other parameters.

B. <u>Charge Balance</u>

The projected water quality results have significant inconsistencies in the cation-anion charge balance. The charge for each ion is calculated from the concentration by dividing the concentration (in mg/L) by the equivalent weight (the atomic weight of the ion divided by the charge on ion) to obtain the concentration of charge from that ion (in mequiv/L). The total charge (the sum of the cations and anions) in solution has to be zero, so as the total cation charge must equal the total anion charge. The charge balance calculations are shown below in Table 2.1.3 below (excerpted from Table 14 of GRE, 2017):

Table 2.1.3: Charge balance of major ions given for PTS influent (GRE, 2017; Table 14)

Cations				Anions			
Parameter		Concentration		Parameter		Concentration	
ID	Equiv. Weight	mg/L	mequiv/L	ID	Equiv. Weight	mg/L	mequiv/L
H^+	1	(pH 3.92)	0.12	Cl^-	35.5	0.215	0.61
Al^{3+}	9	27.2	3.02	SO_4^{2-}	48	97.3	2.03
Ca^{2+}	20	12.5	0.63				
Mg^{2+}	12	5.11	0.42				
K^+	39	6.39	0.18				
Total Cation Charge			4.37	Total Anion Charge			2.63

Charge Balance Error (CBE) = (total cations-total anions) / (sum of anions and cations) = 24.9%. This error is higher than the acceptable CBE of (less than ±5%) (Standard Methods, 1999). Possible causes for electrical imbalance are: 1) laboratory errors; 2) some species

[18] Refer to Section 2.1.1.2 of this report for descriptions of ARD processes.

(major ions) are not measured; and/or using unfiltered samples that contain solids which dissolve during sample preservation in acid.

There is clearly much more cationic charge than anionic charge in the Amulsar water samples. In ARD, the cationic charge comes primarily from the H^+ and Fe^{2+} (and other metals but to a lesser degree), while the anionic charge comes from SO_4^{2}. The oxidation and subsequent precipitation of ferric oxides results in the generation of H^+, which carries the positive (cationic) charge. Reactions between the acid and aluminum bearing rocks transfers the positive charge to aluminum. However, sulfate remains as the primary anionic charge. Therefore, the problem is that the charge from the sulfate concentrations in the PTS water do not balance the charge from the aluminum. Golder (2014f) states that sodium and fluoride are used to balance slight differences in the charge balance during the modeling, but to have fluoride account for the charge difference in Table 2.1.3 would require a fluoride concentration of 33 mg/L, which is unrealistic as demonstrated by the Amulsar surface water, groundwater and rain water monitoring results (Lydian 2018; Golder 2019). Also, Table 2.1.3 shows no sodium in the incoming water to the PTS. Sodium is usually a major cation in water, and if there is much sodium in the water, the charge balance would become even worse. The charge balance discrepancies further raise concerns about the reliability of the model projections and water quality.

C. *Aluminum concentrations inconsistent*

The water quality model predictions (GRE, 2017; Table 14) and data used in the PTS design basis (Sovereign, 2015) are different as shown in the comparison in Table 2.1.4 below.

Sovereign (2015) states that they have modified the PTS incoming water quality given in Table 14 (GRE, 2017) by increasing the iron concentration to be more realistic, but do not mention that they lowered the aluminum concentration by an order of magnitude. The nitrate concentration has been increased to account for blasting residue as estimated by Golder (2014f). (This last point will be discussed in more detail later.) Since the design of the PTS depends on having aluminum concentrations below 2 mg/L, the decrease in aluminum concentration from 27.2 mg/L to 2.27 mg/L is significant. The value of 27 mg/L (GRE, 2017 Table 14) indicates the selected PTS system (with a design criterion of less than 2 mg/L for aluminum) was not appropriate for this water quality.

Table 2.1.4: PTS Influent quality predictions (GRE, 2017) vs. PTS design basis (Sovereign 2015)

Parameter (*)	GRE (2017)	Sovereign (2015)
pH	3.92	3.5
Aluminum, mg/L	**27.2**	**2.27**
Calcium, mg/L	12.5	Not given
Chloride, mg/L	0.215	Not given
Iron, total, mg/L	**5.66E-07**	**3.22**
Magnesium, mg/L	5.11	Not given
Manganese, mg/L	0.0016	0.002
Nitrate, mg/L	**2.35**	**42**
Potassium, mg/L	6.39	Not given
Sulfate, mg/L	97.3	105

(*) Shaded numbers reflect parameters with discrepancies between water quality model projections (GRE, 2017) and data used for the PTS design (Sovereign, 2015)

This discrepancy is further elaborated by comparing the PTS influent data (Sovereign, 2015) to water quality from various test results and data sets including HC and modelled concentrations of key parameters for the BRSF seepage and underdrain (GRE, 2014g). Concentrations for the key parameters are given in mg/L in Table 2.1.5 and in mequiv/L units in Table 2.1.6.

Table 2.1.5: Comparison of water quality for BRSF leachate in mg/L

Location	Water Quality				
	pH	Acidity	Fe	Al	SO_4
		mg/L as $CaCO_3$	mg/L	mg/L	mg/L
Measured Values					
Humidity Cell–74-C (week 20)	2.5	960	125	38	980
Humidity Cell–76-C (week 20)	2.8	470	115	18	440
Modeled Values					
BRSF Seepage - post	3.02	962.8	0.5	164	412.3
BRSF Underdrain - post	3.88	171.6	0.0	30	105.4
PTS Input – GRE (2017)	3.91	159.6	5.88 E-07	27.6	98.8
PTS Input – Sovereign (2015)	3.5	Not given	3.22	2.27	105

(GRE, 2017; Sovereign, 2015; GRE, 2014g)

Table 2.1.6: Comparison of water quality for BRSF leachate in mequiv/L

Location	Water Quality				
	H^+	Acidity	Fe (as Fe(III))	Al	SO_4
	mequiv/L				
Measured Values					
Humidity Cell–74-C (week 20)	3.2	19.2	6.68	4.2	20.4
Humidity Cell–76-C (week 20)	1.6	9.4	6.1	2.0	9.2
Modeled Values					
BRSF Seepage - post	0.95	19.3	0.03	18.2	8.6
BRSF Underdrain - post	0.13	3.43	0	3.3	2.2
PTS Input – GRE (2017)	0.12	3.19	0	3.1	2.1
PTS Input – Sovereign (2015)	0.31	-	0.17	0.25	2.2

(GRE, 2017; Sovereign, 2015; GRE, 2014g)

Acidity at these pH values and in ARD comes from the sum of H^+, Fe^{3+}, and Al^{3+}. Since these ions should be the major cations in the leachate, they also add up to the cation charge. The major anion is sulfate, and so the acidity should be equal to the sulfate concentration (in mequiv/L units). For the HC leachates, these relationships hold. Sulfate concentrations for the HC leachates in Table 2.1.6 are close to the acidity values, while the H^+, Fe and Al concentrations are close in Cell 76-C, and relatively low in Cell 74-C. (The charge balance for Cell 74-C is much better if the Fe is assumed to be Fe(II), in which case the concentration is 10.02 mequiv/L). The modeled results show a good correlation between the acidity and the cations, but significantly lower sulfate concentrations than either the acidity or the cation concentrations. This discrepancy in sulfate concentrations raises concerns and further increases uncertainty in the system design.

The modeled water quality is dependent on a number of factors that could be different from that originally modeled. For example, the Site-Wide Water Balance (Golder, 2018) indicates that changes in design of BRSF have changed the leachate water volumes estimated in the previous model (Golder, 2016a). Further, estimates of the water going through the BRSF may be low (see Sections 2.1.2.2 and 2.1.2.3 of this report). Presumably, this will alter the proposed water quality projections. These changes have not been incorporated in water quality modeling since the model was reported in 2014. The BRSF leachate is not the only water going into PD-8. In addition, water from the mine pits will be discharged into the pond and will interact with the water from the BSRF. The water quality from the mine pits has also been modeled, but there is no indication that the water quality of the mixed water (which is what will go into the PTS) has been modelled, nor has there been much effort made to evaluate the changes in water quality after the mine pits are closed. Such changes highlight the uncertainty in the water quality modeling, and the risk in design treatment systems based on projections that may change.

2.1.5.4.1.4 PTS Design

GRE (2017) provides an updated ARD Management Plan while Sovereign (2015) provides the basis of the PTS design. The design is based on incoming water with low iron and aluminum concentrations. Water with higher iron and aluminum concentrations is treated using a different sequence of steps according to the GARD Guide (INAP 2009). While the modeled water has low metals concentrations, there is no guarantee that the model is correct and no ability to adjust the system for high iron and aluminum concentrations if the modelling is not correct.

The unit operations considered for the PTS (*i.e.,* nitrate reduction and sulfate reduction) are well established technologies and are used for mining-influenced water (ITRC, 2013; USEPA, 2014). Sulfide removal is less common. However, nitrate and sulfate bioreactors have been used on old mines with fairly constant flow and water quality, whereas, the proposed PTS is for an operating mine and for the first years after closure when both flow and water quality will vary. A key discrepancy is that the design (Sovereign, 2015) does not elaborate what happens to the acid, or why the two manganese removal beds are necessary.

Gusek *et al.* (2018) presented the results of bench scale testing on some parts of the proposed system in a paper at the Tailings and Mine Waste Conference in Colorado, USA, in 2018. The testing initially used simulated mine water spiked with nitrate and sulfate with pH adjusted to a representative value, then later used locally sourced acidic water with low metals concentrations (from a former mine in Armenia). The test reportedly demonstrated that the nitrate and sulfate reducing bioreactors were effective, provided that there was sufficient limestone to keep the pH neutral. The sulfide removal reactor was less successful, but could be improved in future testing. While it is valuable to have the bioreactors demonstrated, the focus again is on post-closure water with low metals concentrations. The testing did not address what would happen if the iron and aluminum concentrations were higher than projected in the water quality models.

2.1.5.4.1.5 Nitrate and Ammonia

The ARD Management Plan and PTS design basis focused on water quality at one point in the mine life, namely post closure. But the BRSF PTS is intended to treat water during the mine operation phase (during the last five years[19]) and during the post-closure phase. The water quality during these two phases will be significantly different. During mine operation, Golder (2014f) estimated that water coming from the mined rocks (both the pits and the BRSF) will

[19] Based on the updated SWWB (Golder, 2018), all contact water from the BRSF and pits during the first five years of mine operation, will be used in the HL process, and there will be no water to treat. However, this 5-year period may be overestimated due to the incorrect water fluxes from the BRSF and the pits.

have significant concentrations of both ammonia and nitrate from the explosive residue. Golder (2014f; Table 2) estimated the concentrations as shown in Table 2.1.7

Table 2.1.7: Estimated nitrate & ammonia levels in pits & BRSF water (Golder, 2014f; Table 2)

Area	Nitrate Concentration (mg/L N)		Ammonia Concentration (mg/L N)	
	Minimum	Maximum	Minimum	Maximum
Pit Sumps	12-30	>1000[1]	12-30	>1000(*)
Pit Backfill	70	440	70	440
BRSF Fluids	13	420	13	420

(*) Significant uncertainty in the high concentration, low volume sump water

The estimated average concentration in the pit sump water is between 70 and 180 mg/L N each for nitrate and ammonia for the time period that the excess pit water will be sent to the PTS. These concentrations will decrease rapidly after the mine is closed, since both nitrate and ammonia will be rapidly leached from the mined rock.

The estimated flow from the pit sumps is 250,000 m^3/year for years five through nine, while the seepage from the BRSF is estimated at 63,000 m^3/year (2 L/sec). It is not clear from the reports how much of the pit water will be sent to the PTS, but if it constitutes a significant portion, the water coming into the PTS could contain on the order of 100 mg/L nitrate and 100 mg/L ammonia. These values are significantly over the criteria for surface water (0.4 mg/L NH_4 and 2.5 mg/L NO_3 for Type II water in Arpa River basin, which is intended as the discharge water body). Thus, the water will need to be treated.

The projected influent PTS nitrate concentration during operations in the incoming water for the PTS used by Sovereign (2015) is 2.35 mg/L, while the post closure nitrate concentration is projected to be 42 mg/L. These numbers are questionable since the highest concentrations should be during operation not after, and are contradictory to the projected nitrate concentrations from Golder (2014f) estimates.

Furthermore, there is no projected concentration for ammonia in the influent water for the PTS. Sovereign (2015) states that ammonia will be oxidized in PD-8. However, the projected water quality indicates that this water will be acidic (pH 3.5-3.92, depending on stage), and nitrifying bacteria require neutral conditions of between pH 6.5 to 8.5 (USEPA, 2002). Further, it is not clear that the pond will be oxic, If the incoming water contains significant ferrous iron (as it might form the ARD), then the water could be anoxic. Also note that the requirements for the PTS system chosen is for a DO content of < 1.0 mg/L. If the DO is this low, then ammonia will not be oxidized in the pond, since nitrification is an aerobic process.

Moreover, treatment of the nitrate and ammonia during the last five years of the mine operation when the PTS is treating the water from both the BRSF and the excess water from the pit sumps needs to be addressed. The focus of the PTS discussion has been on treating ARD water from the BRSF, while the need to treat the two nitrogen species has been less highlighted. Obviously, the nitrate reduction ponds are designed to treat the nitrate, but the incoming concentrations would appear to be off, and there is no discussion of how ammonia will be addressed.

2.1.5.4.1.6 Summary

- The system design using a passive system has been selected much too early in the process and does not allow for the flexibility needed to deal with such a complex water treatment system. The design is based on modelled water quality that may or may not be valid. If the modelled water quality is not valid, then the system will likely fail.

- The GARD Guide (INAP, 2009) indicates active water treatment system is most appropriate during mine operations. A passive system is more appropriate for treatment of water with low chemical concentrations and steady water flux after the mine has closed. Since water will need to be treated during the last five years of mine operation, an active system will be more appropriate.

- The water quality modeling has significant discrepancies and uncertainties that raise significant concerns about the reliability of water quality projections and ultimately the feasibility and effectiveness of the proposed PTS.

    a. The modelled iron concentrations are much too low for natural waters, especially waters impacted by ARD.

    b. The charge balance for cations and anions in the incoming water for the PTS has a large error that significantly exceeds the acceptance criterion.

    c. The aluminum concentrations are inconsistent in different descriptions of the incoming water for the PTS.

    d. The water quality modeling was done early in the mine planning. Changes to the site-wide water balance and design, especially as related to water in the BRSF may impact the projected water quality.

    e. During the years of mine operation, the water coming into the PTS will contain both water from the BRSF and excess water for the pits that is not used in the heap leach operation. The influence of the pits water on the overall water quality has not been included in the model. This is important, especially after the updated site-wide water balance.

- Ammonia in the wastewater will be present at concentrations in excess of the regulatory discharge criterion, but the treatment process for the ammonia is not discussed except in brief and extraneous comments. Although discussed, Nitrate treatment requires further and more robust evaluation. Nitrate and ammonia are likely to be the major contaminants along with the products of ARD that require treatment while the mine is operating.

  The current PTS is not designed to treat ammonia during mine operations and will not be able to treat concentrated and complex ARD during and shortly after cessation of mine operations. If the PTS fails, high nitrate and ammonia concentrations and ARD could be discharged to the Arpa River with potential impacts to the surrounding water bodies.

2.1.5.4.2 HLF

2.1.5.4.2.1 Overview

Metals are extracted from the ore at the HLF by spraying an alkaline cyanide (sodium cyanide - NaCN) solution on the heap leach (HL) pile of ore, allowing it to percolate through the ore. The pregnant leach solution is collected in a pond next to the pile, then sent to a processing facility - adsorption/desorption/recovery (ADR) plant - to remove the gold and silver cyanide complexes onto activated carbon. The water (the barren leach solution) is replenished with fresh cyanide and base and then returned to the HL pile for further leaching. The metals are extracted from the carbon with hydrochloric acid (HCl), which is then neutralized with NaOH. Silver and gold are precipitated by adding zinc metal, and the solids removed for processing. The solution is returned to the barren solution tank for reuse.

Water in the process is recycled, with no discharge during the HL operation. The ADR plant uses 1,050 tons per year NaCN, 531 tons per year HCl and 190 tons per year of sodium hydroxide solution, with the liquid effluent going to back to the HL operation (Table 3.14 in Section 3 of the ESIA). In addition, water from the BRSF and the mine pits is discharged into the HL water. After year 5 of the mine operation, there may be excess water from the BRSF and mine pits, which is discharged to the PTS for the BRSF.

At the end of mine operation, the ore pile continues to be leached until the gold is extracted, then it is rinsed with fresh water with hydrogen peroxide added to destroy residual cyanide. This water is collected separately. Following rinsing, the pile is capped and any leachate after capping is treated in a PTS designed just for the HL water. Lydian states that it is difficult to predict what will be in the heap pile leachate, that it is difficult to design a treatment system for this water at this point, and that the design will be done after a better understanding of the water quality of the HL water is available. The deferral of a final detailed design of the PTS until after mining operations start is a reasonable approach. What could be added is a plan for how to and who will monitor the HLS and design the system so that it is not neglected as mining operations are shut down.

There are, however, several concerns about the HLS characterization, treatment, and discharge.

2.1.5.4.2.2 Water Quality Projections

Table 2 of the Hydrogeologic Risk Assessment - Proposed HLF (Golder, 2014b) presents water quality data for both the final HL solution and for the solution after detoxification. The concentrations for key parameters are given in Table 2.1.8 below.

Table 2.1.8: Key Water Quality Parameters - HLF Solutions (Golder, 2014b; Table 2)

Parameter	Units	Final Barren Solution		Final Detoxified Solution	
		Test 61781	Test 61790	Test 61781	Test 61790
Alkalinity, total	mg/L as $CaCO_3$	490	330	360	170
Bicarbonate	mg/L as $CaCO_3$	83	<1	130	120
Carbonate	mg/L as $CaCO_3$	260	190	160	43
Hydroxide	mg/L as $CaCO_3$	<1.0	3.4	<1.0	<1.0
Aluminum	mg/L	1.1	6.6	0.38	2.4
Calcium	mg/L	1.6	7.8	4.2	13
Chloride	mg/L	41	27	28	27
Cyanide (total)	mg/L	42	67	0.66	0.61

Parameter	Units	Final Barren Solution		Final Detoxified Solution	
		Test 61781	Test 61790	Test 61781	Test 61790
Fluoride	mg/L	1.8	2.9	1.9	2.8
Iron	mg/L	0.24	0.91	0.2	0.12
Magnesium	mg/L	<0.50	<0.50	<0.50	<0.50
Nitrate	mg/L	1.4	0.96	3.0	2.5
TKN	mg/L	76	80	20	29
pH		9.99	9.74	9.91	9.23
Potassium	mg/L	14	45	15	48
Sodium	mg/L	310	408	260	340
Sulfate	mg/L	45	390	140	590
TDS	mg/L	770	1200	720	1200

There are several issues with this table and the projected water quality for the spent HLS.

Firstly, the water quality is taken from a study by Kappes, Cassidy and Associates (2012) on the effectiveness of cyanide to recover gold from the ore. The testing included looking at whether peroxide could be used to destroy cyanide once gold extraction was complete. The testing was not intended to evaluate how the water quality of the HLS would be after ten years of operation with continuous recycling and cannot be used for that purpose, for several reasons:

- The reagents used in the laboratory testing are relatively different from those to be used in the full-scale operation, namely the laboratory testing used lime (CaO) to raise the pH whereas the full-scale operation will use sodium hydroxide (NaOH). The calcium and sodium concentrations in the laboratory testing are not representative of field solutions.

- More importantly, the HL water will be recycled for ten years in the HLF operation with no discharge. NaCN, NaOH, and HCl will be added at each pass through the pile (with a 60-day cycle, this corresponds to around 60 cycles). The concentrations of the continually added soluble ions (sodium, chloride) will increase, as will sulfate from the rock. Yet, the table shows the concentrations of sodium based on the concentration added in the initial wash of the HL pile. This is unrealistic, particularly when considering mass accumulation due to continued water loss due to evaporation in the HLF and contact water ponds. For the soluble ions such as sodium, chloride, nitrate, and sulfate the concentrations given are obviously too low, which would result in underestimating corresponding loading to and treatment requirements at the PTS. In addition, for the other metals that may be extracted from the ore itself (many of the trace metals), the concentrations after ten years of use in leaching the ore and recycling likely to be much higher than the concentrations in the original solution.

- Attachment 1 of Golder (2014f) estimated that the blasted ore in the heap pile is expected to contain between 234,058 and 585,156 kg of nitrogen (both as nitrate and ammonia) from the blasting operation over the life of the mine. This nitrogen (N), both as nitrate and ammonia, will rapidly leach into the HL solution. Unless there is a loss in the ADR discharge, this will give a very high concentration of nitrogen (probably as nitrate) in the HLS. If the heap pile contains over 1,000,000 m^3 of water (Golder, 2018) after rinsing, this gives a final concentration of 200 to 600 mg/L N in the water from the blasting residuals. This does not include the nitrate and ammonia coming from the mine pits and from the BRSF facility, the water from both of which goes completely to the HL water for the first five years. The values of 1.4 and 0.96 mg/L in Table 1a for nitrate in the final barren solution likely underestimate the actual nitrate concentrations by orders of magnitude. Golder (2014f) did not estimate the concentration of nitrogen in the HLS due to other sources of nitrogen, saying the analysis was outside the scope of the memorandum.

- The water being sprayed on the pile is at a pH of 11-12. Water at such a high pH will scrub carbon dioxide (CO_2) from the air to form bicarbonate and carbonate. After ten years of use and recycling, the bicarbonate and carbonate concentrations in the HL water should be quite high. Yet the bicarbonate concentrations in the barren heap solutions in Table 1a above are relatively low. Some carbonate will be removed by reaction with the lime in the rock pile, however, the calcium concentrations given do not reflect the solubility of calcium carbonate, so it is not clear that such precipitation was considered.

The alkalinity values in Table 2.1.8 are inconsistent. Total alkalinity is the sum of bicarbonate, carbonate, and hydroxide alkalinities by definition and by the way they are measured. However, the total alkalinities shown in Table 2.1.8 are considerably higher than the sum of the three components. A comparison of the alkalinities is presented in Table 2.1.9 below.

Table 2.1.9: Comparison of Alkalinities – HLF Solutions (Golder, 2014b; Table 2)

Parameter	Units	Final Barren Solution		Final Detoxified Solution	
		Test 61781	Test 61790	Test 61781	Test 61790
Alkalinity, total	**mg/L as $CaCO_3$**	**490**	**330**	**360**	**170**
Bicarbonate	mg/L as $CaCO_3$	83	<1	130	120
Carbonate	mg/L as $CaCO_3$	260	190	160	43
Hydroxide	mg/L as $CaCO_3$	<1.0	3.4	<1.0	<1.0
Bicarbonate + carbonate + hydroxide		**343**	**193.4**	**290**	**163**
pH		9.99	9.74	9.91	9.23

These values are simply incorrect as presented. The hydroxide alkalinity is measured from the amount of acid required to bring the pH down to 10.3. At a pH of 9.74, the oxide alkalinity is 0.0 by definition. Therefore, one cannot have a hydroxide alkalinity of 3.4 mg/L $CaCO_3$ at pH 9.74 as shown for Test 61790.

Alkalinity is a measure of the acid-neutralizing ability of the solution. The most common sources of alkalinity in natural waters or wastewater are the carbonate species, hence, the divisions in measurement. If the carbonate species are the primary sources of acid-buffering, then the bicarbonate alkalinity will always be higher than carbonate alkalinity, since any carbonate present in the sample is measured in both sections of the titration. However, other bases can contribute to alkalinity, such as cyanide and ammonia. These would show up primarily as carbonate alkalinity rather than as bicarbonate alkalinity. As discussed above, alkaline water that has been in contact with the atmosphere for ten years should have very high concentrations of both carbonate and bicarbonate, and the alkalinity results should reflect these high concentrations. The values shown in the Table 2 are questionable.

Moreover, the laboratory results sheet for the Kappes-Cassidy (2012) study presents a charge balance for the water quality. However, the charge balance results are inconsistent with the water quality, since in some samples the charge from sodium is greater than the total cationic charge.

Kappes-Cassidy (2012) study was performed to evaluate the effectiveness of cyanide at recovering gold and the ability of peroxide to destroy the cyanide, where water quality results may arguably be peripheral to the point of the study. However, the use of its questionable water quality data to model the water quality of the final leach solution, design the PTS, and assess the potential environmental impacts and compliance is problematic and untenable.

2.1.5.4.2.3 HLS Treatment

At the end of the heap leaching operation, it is not clear what happens to the HLS used in the HL operation. GRE (2014d) states the following (Section 2.1.2.2; page 8-9):

> GRE indicates the following processes occur following cessation of ore deposition on the heap:
>
> - For a period of six to ten months, "rinsing" of the heap occurs. This comprises continued irrigation of the heap with sodium cyanide solution and circulation of leach solutions to the processing plant to recover any remaining precious metals from the ore. No source term attenuation is anticipated during this period. It is assumed that active evaporation to reduce solution volumes may be undertaken toward the end of the period.
> - Following the rinsing period, a detoxification process is undertaken where the heap is leached with hydrogen peroxide solution to destroy the cyanide in the heap and solution. This process will continue for six months to one year until cyanide concentrations are sufficiently reduced to permissible levels to discharge, and
> - Following rinsing and detoxification, the facility is covered and passive drawdown of the leach solution occurs. Closure management continues for a further five years during which drainage from the heap is sent to a passive treatment system and is monitored prior to discharge.

A flow chart of the water management during the closure phase presented as Figure 6.10.3 in Chapter 6.10 of the ESIA is shown below as Figure 2.1.2. The water from the residual leaching and rinsing are shown going to the ADR plant, and then inexplicably disappearing. GRE (2014d; page 71) gives an estimate of 2 million m^3 of water in the HLF after rinsing. The water by this time has been in circulation for ten years and will have elevated levels of sodium, chloride, sulfate, nitrate and probably other ions as well. Assuming the volume of HL solution is in the same range as that remaining in the HLF after rinsing (*i.e.*, >1,000,000 m^3), the management and disposition of such large volume of contaminated water should be addressed.

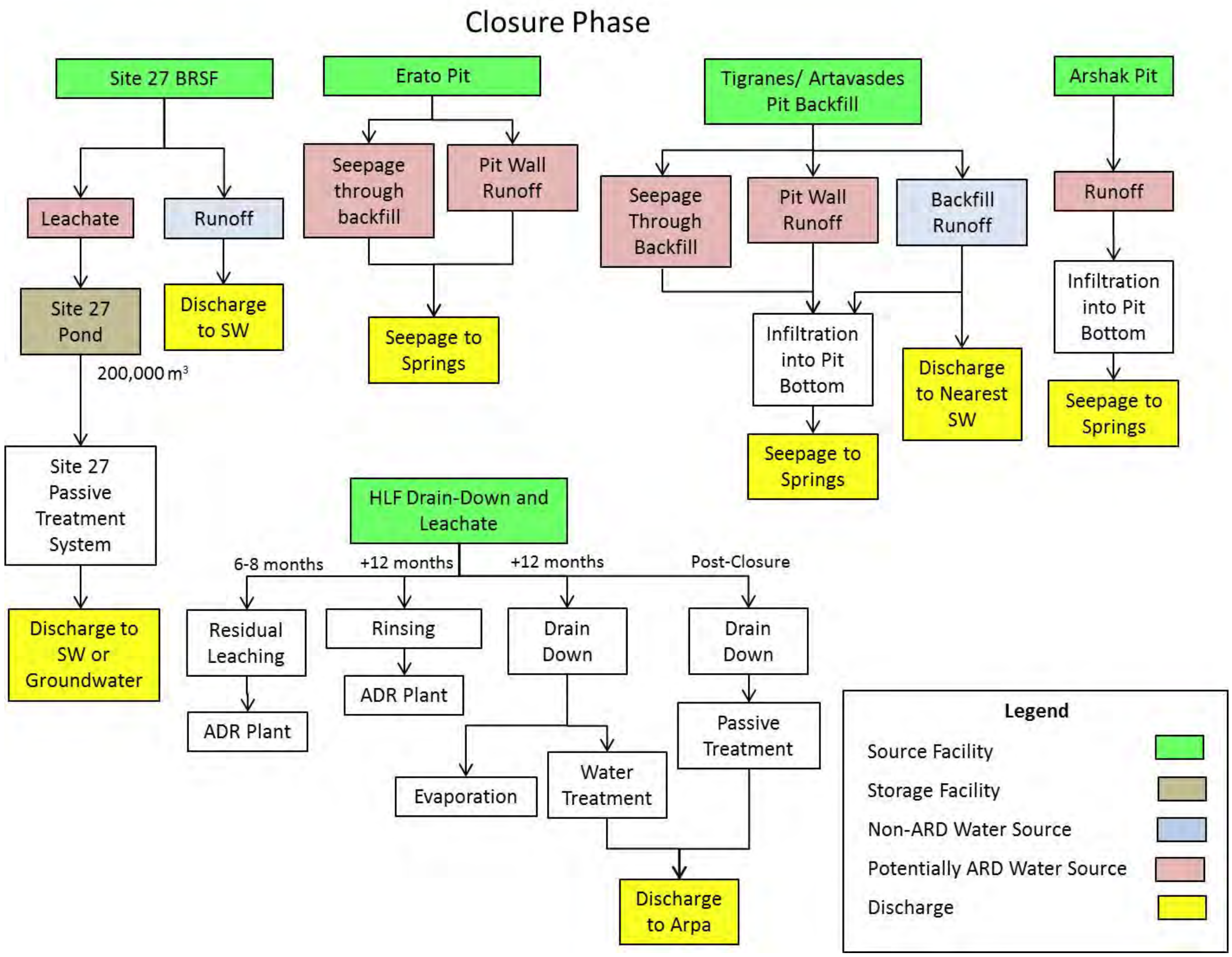


Figure 2.1.2: Flow Chart - Water management during closure phase (Figure 6.10.3 of the ESIA)

The ESIA proposes a dedicated PTS to be designed and implemented upon closure based on post-closure water quality monitoring and present generalized descriptions of processes for treating the leachate from the HLF post closure. This may be a reasonable approach; however, the ESIA should include plans for laboratory treatability and pilot testing to evaluate and confirm the feasibility and effectiveness of the PTS in treating the HLS and leachate and in achieving the discharge criteria. Furthermore, there are no contingency plans in case of the PTS failure to effectively treat the HLF wastewater or in future cases of PTS failure or emergency.

2.1.5.4.2.4 Summary

The discussion of the heap leaching operations solutions has two major issues:

- The projected water quality at the end of operation, both before and after cyanide treatment is unrealistic. The water quality used for modeling the system comes from tests that were not designed and not appropriate for assessment of environmental impacts, treatment, and compliance of the wastewater, and the water quality results have internal inconsistencies indicating that some of the results are incorrect. Further, at the end of the mine operations, the water will have been in circulation for ten years, and will have elevated concentrations of soluble constituents (sodium, nitrate, chloride) added to the water from operations and elevated concentrations of trace constituents leached from the ore (sulfate, trace metals) that will require treatment prior to discharge. There is no good modeling of these concentrations to know what to treat and how to treat them.

- There is no indication of how the HLS (the barren solution after the pass through the ADR) will be managed and treated and only a limited discussion of how the rinse water will be treated. This water may be on the order of 1 million m^3 and may contain high concentrations of ions that can be difficult to treat (sodium, chloride, nitrate...), so how it is handled is important to prevent contamination of the receiving surface water.

  The water coming from the HL ore pile after it is covered will be treated in a PTS to be designed at some point in the future after obtaining actual water quality data. Although PTS is a potentially applicable treatment technology for the post-closure HLF solution and leachate, there are no plans for laboratory treatability or pilot testing to assess the feasibility and effectiveness of PTS. Furthermore, there are no discussions of contingent or supplemental plans in case of the PTS failure to effectively treat the HLF solution and leachate and no contingency plans for future PTS failure or emergency.

The reports are not clear on how the HLS will be treated immediately after mining operations cease, thus it is difficult to determine whether treatment will be successful or what the impacts are if treatment is not successful.

2.1.5.5 Catastrophic Events

River flood risk is extremely low. The Mine facility closest to a river in distance and in elevation is the HLF, which is at least 200 m above the Arpa River. The Arpa River is a managed watercourse, with mitigation of flood provided by the Kechut Reservoir.

Consistent with the IFC standards, the current design of the contact water ponds includes free-board for the 100-year, 24-hour storm.

The seismic hazard risk is high for the Project Area. Seismicity was considered in the design of the HLF, BRSF, open pits, crushing plant, and overland conveyor system. However, an old construction standard was used for the analyses. Furthermore, known faults within the Project study area were not considered in the seismic hazards analysis. Movement on the seismically-active PSSF fault system could cause fault slip in the study area, potentially compromising the liner beneath the BRSF and the cover and destabilize the waste rock pile (Zirak Fault beneath BRSF). This fault could conduct ARD-impacted seepage water from the BRSF toward the Kechut Reservoir and/or to the Vorotan River. Fault slip on the Agarakadzor Fault passing through the vicinity of the pits and BRSF could also impact the stability and integrity of the BRSF and pit backfill and cover systems. Ground motion could also impact the stability of the HLF, liner, piping, and cover and inflict damage on the contact water channels, the PTS, and system of process and stormwater ponds, resulting in contact water being released to surface water and groundwater.

Covers on the BRSF and pit backfill can be restored, if impaired by earthquakes. The repair of breached liners beneath the BRSF and the HLF will be challenging, requiring temporary or permanent relocation of the rock and spent ore. A destabilized BRSF or pit backfill could result in permanent loss of the non-acid generating VC layer of rock between the cover and the PAG rock. Any exposed PAG rock on pit walls or in the BRSF, HLF, or pit backfill due to earthquakes could impact the environment for hundreds, or possibly on the scale of a thousand or more years.

Historic landslides surrounding the Amulsar Mine are not documented in the ESIA, EIA, or supporting documents. Potential landslides are addressed in Section 2.4.4 of the EIA in the context of slope stability in the mine pits based on geotechnical data acquired through the exploration drilling program. The assessment is based on rock strength, RQD data, and orientation of discontinuities determined from rock core and includes the likelihood of earthquake-induced rock avalanches, slides, and slumps. The assessment does not pertain to the potential activation and consequences of landslides induced by blasting that would affect the environment and/or communities surrounding the Project. The Golder (2013) earthquake hazard assessment does not address the potential for landslides resulting from blasting. An assessment of potential landslide activation and the consequences is not possible with the available information.

The revised construction standard should be reviewed for compliance of all mining infrastructure including the need for reinforcement or double containment of piping.

2.1.5.6 Post Closure Cost

The Amulsar Mine closure cost bases and estimates are provided in Appendix 8.18 of the ESIA. The cost was reviewed for general consistency with standard practice. The cost estimates cover the major scope items. However, some cost items are questionable and the overall cost appears to be underestimated. Below are some of the key concerns:

- The post closure operation, maintenance & monitoring (OM&M) period is limited to <u>only five years</u>. In the US, regulatory requirements and guidelines for closure (e.g., RCRA 40 CFR Part 264.117; Nevada NAC 445A.446; USEPA, 2000) indicate post closure costs should be calculated for a revolving 30-year period[20] (minimum), especially when contamination sources remain. Post closure costs should include routine OM&M activities as well as periodic replacement, maintenance and repair actions that will be required after 5 years (e.g., treatment system components, liners, covers, containment systems, monitoring wells/points, piping, etc.), which can be significant. The shortened post closure monitoring period and the omission of the periodic replacement/maintenance costs will result in significantly underestimating the post closure costs. Clarifications of cost impacts of longer post closure monitoring duration are presented below:

    i. Appendix 8.18 of the ESIA provides a cost of $5,558,510 for monitoring and maintenance of the PTS. There is no breakdown for this cost. However, a footnote in the Cost Summary table (page 3 of 123 in Appendix A) indicates "*additional documentation required*."

       Using the post closure period of five years assumed in the ESIA, the equivalent annual routine OM&M cost is estimated to be approximately $1.1M. Accordingly,

[20] The reference is to a revolving 30-year period whereby every year is year one, because the financial assurance should be reevaluated and updated annually.

the unadjusted cost (*i.e.,* without indirect cost) for the PTS OM&M alone for 30 years will be approximately $33.4M. The total cost will likely be higher due to the need to account for periodic maintenance and replacement items that occur after five years (not included in the ESIA costs) and the indirect and technical support costs. In fact, adjustment for the indirect cost referenced in the ESIA at a total of 21.3% (*i.e.,* 6% contingency, 10% contractor profit, and 5.3% contract administration) will result in a total cost for the PTS OM&M to be approximately $40.5M without adjustment for periodic replacement costs or realistic contingency (see comment below about contingency).

ii. Appendix 8.18 of the ESIA provides a cost of $410,576 for monitoring, which includes $286,252 for rehabilitation monitoring and maintenance and $124,324 for groundwater and surface water monitoring).

Similar to the PTS OM&M cost (based on a 5-year post closure monitoring period), the equivalent annual monitoring cost is estimated to be approximately $82,000. Accordingly, the unadjusted cost of monitoring for 30 years will be approximately $2.5M. The total cost will likely be higher due to the need to account for periodic maintenance and replacement of monitoring systems that occur after five years (not included in the ESIA costs) and the indirect and technical support costs. In fact, adjustment for the indirect cost referenced in the ESIA at a total of 21.3% will result in a total cost for monitoring to be approximately $3M (without adjustment for periodic replacement costs or realistic contingency).

iii. Combining items i and ii above with the other costs remaining unchanged indicates the total Mine rehabilitation and closure cost will increase from approximately $34M to approximately $70M (without adjustment for periodic replacement costs or realistic contingency).

- Contingency (scope and bid) is too low at 6%. The USEPA (2000) and AACE (2008a; 2008b; 2009) cost estimation guidelines indicate for this level of project development (pre-feasibility) and the high degree of uncertainty (*e.g.*, unreliable data and PTS and need for additional studies, *etc.*), the contingency on several items will likely exceed 20%. The Amulsar feasibility study (SGS, 2014 Table 21.5) used 16% for the initial capital phase. Clarifications of the effect of a more realistic contingency on the cost are presented below:
    - Using a more realistic contingency of 20%, the total indirect cost percentage would increase from 21.3% in the ESIA to 35.3%. Accordingly, the total rehabilitation and closure cost given in the ESIA will increase from approximately $34M for a contingency of 6% to approximately $38M for 20% contingency, without adjustment for the longer post-closure OM&M duration of 30 years.
    - Using the adjusted indirect cost with a 20% contingency and a 30-year post closure OM&M period, the total rehabilitation and closure cost would be estimated to increase to approximately $78M.

- Treatment scope and costs are unrealistic due to incorrectly assumed low leachate concentrations and mass loading and missing processes as discussed in Section 2.1.5.4.
- Professional/technical costs (design/engineering, project management/administration, and construction management) at approximately 3% of total construction/capital costs (on the order of $1M) are underestimated. USEPA (2000) indicates the professional/technical services are commonly greater than 15% of total construction costs for similar projects. The Amulsar feasibility study (SGS, 2014 Table 21.5) used 10% for the initial capital phase. Using 15% for total professional/technical services would result in an additional increase to the Mine rehabilitation and closure cost on the order of $4M to $5M.
- Many cost items are presented as lump sum without bases and cannot be assessed (*e.g.,* PTS maintenance and monitoring cost provided at $5,558,510 without basis; a footnote in the in Appendix A of the ESIA Appendix 8.18 states "*additional documentation required*").

2.1.6 Environmental Monitoring Program

2.1.6.1 Environmental Monitoring Plan

An environmental monitoring plan (EMP) was developed in June 2016 (Geoteam, 2016b; ESIA Appendix 8.12) for the pre-construction phase and was last updated in August 2018 for the construction phase and additional monitoring (Geoteam, 2018). The EMP includes acquisition of meteorological data at two stations in the Mine area (BRSF and HLF) and monitoring surface water flow and quality and groundwater levels and quality for compliance with RA regulatory standards and requirements, IFC Performance Standards, and of the European Bank for Reconstruction and Development Performance Requirements. The EMP refers to locations, parameters, and frequency for monitoring surface water, springs, and groundwater.

The EMP does not specify locations or details of future monitoring. The Project needs to develop a comprehensive plan for future monitoring (operations, closure, and post-closure). With respect to past monitoring locations, the following observations may be considered for future monitoring.

- Section 2.1.1.5 of this report addresses past surface water monitoring, including river flow and stage monitoring. Locations of continuous and spot flow measurements are posted on Figure 4.9.5 of the ESIA. Figures 4.9.6 and 4.9.7 of the ESIA show the locations of continuous monitoring on the three main rivers and tributaries, respectively. With respect to future monitoring requirements, the continuous flow monitoring stations established by the Project on the Arpa, Darb, and Vorotan Rivers would be generally adequate. A few apparent deficiencies in continuous flow monitoring are in the vicinity of Vorotan Pass. A station at the bend on the upper Darb River, where the course changes from northward to northwestward, would determine whether flow is perennial or ephemeral in that location (given the importance to groundwater flow modeling). Likewise, a station on the east side of Vorotan Pass on the upper reach of the (Porsughlu River?) flowing into Spandaryan Reservoir would serve the same purpose. A station should also be added to the stream below Benik's Pond to monitor potential effects of the Tigranes-Artavasdes pit.

- Surface water quality monitoring is addressed in Section 2.1.1.6 of this report. Surface water quality sampling locations are shown on Figure 4.10.1 of the ESIA. These locations would be generally adequate for future monitoring. A surface water quality monitoring location should be included on the main tributary of the Darb River downstream of station AW006, just before the confluence with the Darb River or just downstream of the tributary on the Darb River, to better assess the Mine impacts on surface water quality.
- Groundwater quality monitoring is addressed in Section 2.1.1.6 of this report. Groundwater and springs quality sample locations are shown on Drawing 4.8.2 of the ESIA. Few springs around Amulsar Mountain and the BRSF have been monitored. Given the importance of springs to livestock and the large number of springs that should be monitored, significantly increasing this number would offset the need for many additional groundwater monitoring wells. Assuming many more springs are added to the groundwater monitoring program, only a few more groundwater monitoring wells would be necessary near the mine pits. These wells should be located north-northwest of the BRSF, southwest of the Arshak pit, and east of the Tigranes-Artavasdes pit.
- Wells for monitoring groundwater levels and quality should also be installed near the Spandaryan-Kechut tunnel. Elevations of the tunnel would be required to determine whether discharge of groundwater is occurring. Tracer studies may be warranted to assess the seepage potential from groundwater into the tunnel.

According to the Cyanide Management Plan (Geoteam, 2016a; Appendix 8.11 of the ESIA), the HLF and process pond designs include sufficient measures to ensure that groundwater and surface waters will not be adversely affected under normal operating conditions. The Leak Collection and Recovery System (LCRS) of the HLF will enable the capture and diversion of any leaks in a closed system. The plan also states that monitoring wells will be installed beneath and close to the HLF location to establish baseline conditions and that additional wells will be required down-gradient of the HLF and solution ponds for pre-construction, construction, operation, closure, and post-closure monitoring of groundwater. Table 13 of the EMP indicates two sets of nested well pairs in the HLF footprint (GGDW013/GGDW013A and GGDW016/GGDW016A) and an additional well up-gradient of the HLF (GGDW011) will be sampled. Drawing 4.8.1 shows GGDW013/GGDW013A and some other wells in the footprint but not GGDW016/GGDW016A. The wells to be monitored down-gradient of the HLF and solution ponds are not specified.

2.1.6.2 Quarterly Environmental Monitoring Reports

Five quarterly environmental monitoring reports were available for review (Q1 – Q4 2017 and Q1 2018).

Nine surface water quality monitoring locations were sampled in Q1 2017. The number of sampling locations increased to a maximum of 16 in the most recent quarterly monitoring report (Q1 2018), which is much less than the number of stations shown on Figure 4.10.1 of the ESIA (39). Notably, no locations on the Darb River or north of the Kechut Reservoir (including Jermuk) were sampled. Most locations north of the BRSF, including the stream in the vicinity of the Madikenc springs, the Spandaryan Reservoir, two locations around Gorayk, and all locations east and west of Amulsar Mountain were omitted. These omissions are unjustified, especially for a deficient baseline dataset (see Section 2.1.1.6).

Five springs and groundwater quality monitoring locations were sampled in Q1 2017. A maximum of 21 locations was sampled in Q4 2017, far less than the number of stations shown on Drawing 4.8.2 of the ESIA (24 groundwater and 28 springs), which itself is deficient in springs sampling locations (see Section 2.1.1.6). There are some differences in locations sampled each quarter. Only one spring (SP83, Madikenc) in the GSA was sampled twice. This sampling program is unacceptable with respect to the number of locations and the deficiency in baseline data (see Section 2.1.1.6).

The monitoring reports do not include potentiometric surface contour maps or contour maps of key constituents in groundwater. There are no time-concentration graphs. There is no discussion of results with respect to previous results and no discussion of analytical methods.

2.2 Biodiversity

2.2.1 Baseline Characterization

2.2.1.1 Best Practice

The baseline characterization section needs to present clear bibliographical review enabling the identification of all habitats related to the project and all species occurring in the area and that could be potentially affected by the project. The section should also present an initial prioritization of the ecological significance of habitats and species.

All references cited should be made available for review and the ESIA/EIA report should clearly refer to date of consultation of the web references; moreover, the scientific literature and reports used to derive georeferenced data and maps should be properly cited and made available for review.

It is important that this section presents maps of main literature findings in terms of species reported and habitats. This should guide the preparation of an ecological significance map which would then guide the survey methodology (areas to be visited and intensity of survey) in view of available data and gaps. This could also serve as an Initial Environmental evaluation to orient project design in an attempt to reduce initial impact.

The baseline characterization section should present a clear methodology for data collection and baseline assessment. For each biological group (receptor) and for key species, the adapted methodology enabling the identification of key focus areas and protocols for field data collection to increase chances to confirm presence of a species should also be presented. This methodology should enable to confirm that all initial ecological significance of habitats and species have been duly considered.

In summary this section should present a synthetic table presenting for each receptor, who did the surveys, when, where, how, and survey field intensity. It should also display a methodological map showing the areas that were surveyed for each species and how the importance of the ecological significance was assessed.

2.2.1.2 Assessment

The Baseline Characterization in the ESIA/EIA presents a general habitat map highlighting nine habitat types but is missing a detailed habitat map showing the 30 habitat types mentioned in the report that would guide the identification of the ecological functionalities of the key species on site.

Information available in the baseline is not synthesized to enable a clear and direct understanding of the hierarchy of ecological significance; it also lacks reference to the status of those species in the Areas of Special Conservation Interest (ASCI) and the Bern Convention, as well as their local status in view of local evaluation of threats.

The baseline characterization section presents a description of species to be considered in the report while only distinguishing priority species (those reported in the Armenia Red Book) and the others. For instance, the report mentions 22 endemic plant species to be avoided where possible, though not in all cases, but refers to very few of those species by name.

Missing as well are quantified observations and locations of observations, and definitions of habitat for each species at stake, with relevant surface areas.

2.2.1.2.1 Habitats and plants assessment

The ESIA/ EIA highlight the importance of Armenia as a center of endemism for wild relatives of domesticated crops and center for breeding and selection of cultivated plants. Moreover, one of the aims of the ESIA/EIA is to protect plants and plant communities that have economic value and are used by others, specifically local people; however, efforts at identifying and conserving economically important plants at Amulsar, more specifically wild edible plants and crop wild relatives is lacking. The ethnobotanical survey is poor as translated, with vernacular, not Latin names of taxa. The ESIA summary explicitly states that the project will significantly change the rural landscape in which local people engage in traditional land management practices, but the project does not undertake efforts to survey and at least conserve the genetic diversity of economically important plants and crop wild relatives at Amulsar *ex situ* (through seed collection and preservation).

The distribution map of *Potentilla porphyrantha* shows all points that were sampled but does not clearly map the critical habitats for this species. The critical habitat of this endangered species is identified as “subalpine meadow with alpine elements” in which the species occurs on suitable rock substrate. The physical footprint of the project is estimated to be on 150.5 hectares (12.5% of the total area of critical habitat). This assumes that the species occupies the entire area of critical habitat (1200 hectares) when it occurs only on a subset of the area where suitable habitat occurs. Therefore, 12.5% is an underestimate of the area occupied by this species. The scientists involved in the assessment of this species seem to have undertaken a count of all individuals; it would have been assumed that such an effort would yield a precise map of where the species occurs in the study area, which would have significantly improved the estimate of project physical footprint and potential mitigation.

2.2.1.2.2 Insects

A clear description of the methodology used to justify the selection of the sampling points, which mostly fall outside the footprint area of the project, is lacking, thus seriously compromising the ability to properly understand the baseline situation.

A detailed map of the *Sedum album* host plant for the *Parnassius appolo* is needed to properly assess the habitat extent for the butterfly.

With regards to beetles, 14 species are reported in the Armenia Red book, of which *Dorcadion bistriatum* Motsch*, Dorcadion sisianum* Lazar and *Dorcadion scabricolle sevangense* are the most vulnerable endemic species of Armenia and should be considered as a conservation priority. *Dorcadion bistriatum* is reported in the vicinity of Ughedzor, Arpa river basin. A map of the habitat of these species of *Dorcadion* (endemic and vulnerable) is missing from the report to enable assessment of the species' potential presence on site.

2.2.1.2.3 Amphibians and reptiles

The report does not highlight the ecological significance of reptiles while two species of vipers *Montivipera raddei* and *Vipera eriwanensis* which are globally reported as vulnerable at International and National scale and reported in the red book and one additional species which is globally vulnerable and protected in the Red book of Armenia *Telescopus falax* occur and are reported in the direct footprint of the project. No further investigations were carried out to properly assess these priority species.

The baseline section lacks a list of key species of concern and a quantified estimation of the areas of suitable habitats that will be impacted.

The ESIA reports that the level of efforts invested for the field survey of reptiles and amphibians is not sufficient (7 days in total, for a total of 1800 ha, over 1 sampling season in non-optimal weather conditions) and yet no additional field work was done to complement this very preliminary assessment. This is especially of concern for the Ursini group of vipers, to which *Vipera eriwanensis* is affiliated. For instance, this viper inhabits very specific alpine steppes which could have been precisely mapped and specific counts could have been undertaken in order to establish the importance of the population. Throughout the report, this vulnerable species is said to be present in the general landscape without any precise scientific justification. Seven days is barely enough time to assess that the species is present without any notion of population quantities.

2.2.1.2.4 Birds

The methodology reported is exhaustive and comprehensive, covering all areas of concern. However, as no night surveys were conducted for the assessment of protected species of birds such as Eagle owl *Bubo bubo,* their overall presence is under evaluated in the baseline. As reported, night surveys were undertaken for the corncrake but surveys for the Eagle Owl should have been carried out earlier in winter when the species exhibit mating calls and territorial behavior.

Mapping and surface estimate of the functional areas for key species of concern (nearly 15) is missing from the ESIA report and should have been highlighted.

Furthermore, the presence of a breeding colony of Lesser Kestrel (*Falco neumanni*) in the Goryak IBA which uses part of the footprint of the project as a key area for hunting during breeding period is not precisely presented, and therefore impacts on this colony are underestimated throughout the report.

2.2.1.2.5 Bats

Functional analysis was performed in April, while activity was measured in May/ June. This enables the evaluation of early reproduction for bats; however, July and September activity measures are essential for assessing the real presence of bats at these altitudes.

Complete functional mapping of the bats is not possible using the given data.

2.2.1.2.6 Mammals

Especially for the Brown bear (*Ursus arctos*), the methodology is comprehensive but presentation of results could have been improved by adding a map with habitat location with respect to project components.

2.2.2 Impact Assessment on Biodiversity

2.2.2.1 Best Practice

To enable proper assessment of impacts on biodiversity (habitats and species), the ESIA/EIA Impact assessment section should provide a clear presentation of project location and geographical extent.

The detailed description of impacts should include the type of impacts (direct/ indirect), a quantified (surfaces of species habitat) estimation of the impact, its geographical extent as well as its duration and consequences. This should serve to evaluate the significance of the impact over the various phases of the project cycle (construction/operation/closure-post closure).

The section should also provide a clear method for the evaluation of the significance of the impacts and should cover the impact on species, habitats (especially key ecological species and critical habitats), as well as protected areas and areas of biodiversity importance.

The report should distinguish the initial impacts (before mitigation), the mitigation measures (avoidance and reduction) and residual impacts (after implementation of mitigation measures). Any residual impact should be addressed in the Biodiversity offset plan to reach a global NNL (no net loss from the project) or when possible a Net Gain.

2.2.2.2 Assessment

The section on impacts in the ESIA presents the mitigation measures instead of presenting the initial impacts and in a separate section the mitigation measures suggested and the resulting residual impacts. This is rather confusing for an evaluator.

The lack of consistent description/nomenclature in the baseline section has led to a confusing identification of the various receptors to be considered in the impact assessment section.

The section lacks a synthesis table showing for each receptor the initial impact, the suggested measures and the residual impact, and displaying figures on the extent and consequences including impact on ecological functionalities.

The impacts from accidental events are also missing from the report.

Monitoring and offset are considered in the ESIA report as mitigation measures. This is misleading to the evaluator as monitoring is part of the BMP (Biodiversity Management Plan) and offset is to be planned to address residual impacts on receptors.

The report includes different estimates of the footprint of the project on different biodiversity elements; for example, the impact is estimated to be 150.5 out of 1200 hectares for *Potentilla porphyrantha* but the total area of impact is 1766 ha + 160 ha which is confusing; for each receptor the report would benefit from a clear table with clearly annotated impacted surfaces.

The evaluation of the significance of the impacts is not based on quantified figures and therefore is not defendable.

As examples:

On habitats and plants

The impact on the subalpine meadow with alpine elements has been under-evaluated – in view of the extent of the areas that will be impacted. The importance of the impact should be “significant”.

For *Potentilla porphyrantha* the report mentions an overall positive impact in the long term. This statement is too ambitious and is not based on conclusive findings in the report.

On reptiles and amphibians

For the vipers (especially in the urisini group), essential data is missing from the baseline to enable proper assessment of the impacts. The ESIA documents a non-significant residual impact without stating specific mitigation measures. The Ursini vipers are protected species, reported Vulnerable at global level, and the impact cannot therefore be considered „Neutral” (as reported in the ESIA). Besides, the justification provided states that these vipers occur in wider landscapes without providing supporting data from the literature to confirm this finding.

On birds

For the Lesser Kestrel, the loss of feeding habitat is not to be considered neutral as the only colony feeding in Armenia is feeding on the project site. Besides, the hunting area of the species is usually close to its feeding area (which is convenient for the chicks and to teach them to hunt during their juvenile phase). In this case the predictive impact is to be considered “significant” both on the ecological functionality and on the Goryahk IBA.

The overall impact of the project on the Goryahk IBA is under evaluated especially in view of the project impacts on Lesser Kestrel and Egyptian vulture.

The Eastern rock nuthatch is a protected species. Residual impacts are not reported properly for this species; moreover, the species should be considered in the offset program.

The ESIA report considers “other birds” as a single group while they all use different habitats and different ecological functionalities for reproduction, nesting, hunting, feeding, resting. They should have been considered separately in view of their specific ecology in order to properly evaluate the impacts.

On Mammals

For the Brown Bear, the report mentions an overall positive impact of the project (presented as Net Gain). This is misleading and uncertain, as we have no guarantee that the Brown Bear will stay in the set aside areas; moreover, the report does not present a quantified estimate of the area of critical habitat of the Bear that will be impacted by the project. The predictive impact should remain “significant” on short and medium terms and offset measures should be considered.

2.2.3 Mitigation Measures

2.2.3.1 Best Practice

The mitigation section should present geolocalized, implementable measures and a map summarizing the measures. It should also describe, for each receptor, the residual impact and the eventual need to include the receptor in an offset program.

2.2.3.2 Assessment

Table 6.9 in the ESIA lists the mitigation measures. Those measures are too general and not always geolocalized to enable their implementation.

Some measures presented in the mitigation section cannot be considered as mitigation; the report suggests (Table 6.11) that monitoring would be carried out, and in case ongoing monitoring proves no residual impact, then in this case, the measures could be revised and reduced. The approach is misleading as mitigation measures should be proposed to address initial impacts, and in case of residual anticipated impact, then an offset program should be properly included. Without these, the IFC PS6 and EBRD PR6 are not properly addressed through this ESIA report.

As examples:

On habitats and plants

Translocation for *P. porphyrantha* should be considered an ongoing experimental measure and cannot be considered as mitigation, since success is not guaranteed.

The mitigation measures suggested for *Potentilla* state that:

> *« If research, monitoring and modelling suggest that pre-mining population size and the extent of the population cannot be restored, a comprehensive review of offsetting options will be undertaken».*

This review should consider protecting the remaining populations of RA if they are vulnerable or threatened. If not, what could possibly be considered for offsetting the loss of such an endangered species? Reintroduction of the species in the restored pits is not really to be considered given that the conditions will not be favorable (altitude will be drastically lower and being in a pit will induce quite different local conditions than summit conditions).

The storage of top soil (40ha) is recommended without clear location of the areas of storage. The report does not mention if these are accounted for in the footprint area calculation.

On reptiles and amphibians

The unique mitigation measure suggested for vipers is related to the reduction of the areas of direct impact; however no specific measures are suggested; moreover, the areas of direct impact for each protected species are not geolocated and their areas are not calculated.

On birds

Monitoring of Lesser Kestrel is a management measure and cannot be considered as mitigation. A possible mitigation for this bird could have been the identification in a close range of the breeding colony of degraded areas for hunting purposes in order to undertake restoration actions.

In addition, in table 6.11.13- it is stated that:

> *"species action plans have been produced but additional data is needed to develop mitigation measures".*

The ESIA should document clear measures and not suggest future (eventual) identification of measures. The precautionary principle should apply in case residual impact evaluation is not possible in view of available results and data.

2.2.4 Environmental Management plans

2.2.4.1 Best Practice

In line with IFC's Performance Standard 6 (2012) (PS6) and EBRD's Performance Requirement 6 (PR6), Lydian International aims to achieve „no net loss' of natural habitat and a „net gain' outcome for any residual impacts on critical habitat.

This section should include:

- Biodiversity management plan
- Biodiversity Action Plan and offset measures
- Mine closure and restoration plan
- Biodiversity monitoring plan

The offset is based on three main principles:

- Like for like
- Same geographical area
- Same time frame (or before) the project's impacts

2.2.4.2 Assessment

2.2.4.2.1 Biodiversity Management Plan (Appendix 8.21)

As presented, the biodiversity management plan is missing the operational section and map detailing the measures, their location, how to implement and who is responsible for implementation, and mostly how will those measures reduce the impact of each receptor (quantified estimates). As such the section is viewed as a “general recommendations” section rather than clear commitment from the project’ owner.

In particular:

Bio 5 does not provide needed details on the surveys to be conducted nor period of the year.

> *“Pre-construction checks (surveys) will be carried out immediately prior to ground disturbance in order to confirm that the biodiversity baseline as reported in this ESIA has not changed significantly and that there are no additional features that should be avoided”*

Bio 8 provides a general statement that can hardly be translated into concrete actions.

> *“As a fundamental design principle, the footprint of Project infrastructure and the areas of land to be cleared will be minimized”.*

Bio 9 should also include avoidance of priority/protected species with its habitat.

Recommendations/ commitments provided in Bio 24 should also be presented in georeferenced/ map form to enable proper evaluation of relevance and location of disturbance.

> *“Where practical, noisy construction-related activity will be avoided at dawn and dusk and during the night (see also noise & vibration impacts)”.*

Bio 44 is missing a map to enable proper evaluation of relevance of the action.

Bio 46 is too vague to enable proper assessment of relevance; it is also not clear what is meant by good examples.

> *“Topsoil storage locations will be chosen to avoid “good” examples of natural vegetation types as well as rocks supporting Potentilla porphyrantha”.*

Bio 50 is missing a map to illustrate the action in relation to the projects’ components.

Bio 53 and Bio 54 are missing details on the monitoring measures.

2.2.4.2.2 Biodiversity Action Plan and Offset Measures (Appendix 8.20)

The establishment of the Jermuk National Park (JNP) is presented as the main offset measure for the project. However, the relevance of the added value of the JNP on biodiversity receptors affected by the project is yet to be demonstrated.

Natural habitats and plants

The "like-to-like" principle of the offset if not clearly demonstrated.

> « *An offset of 837 Habitat Impact Units (HIU) is required to achieve NNL of natural vegetation due to long term degradation and loss associated with Project development* ».

Of those 837 units, only 500 are reported from JNP.

The summary of residual impact highlights the need to offset 22 species of plant, however no evidence is provided on the fact that these 22 species potentially occur in the JNP area. Moreover, a list of the 22 endemic plants concerned is not included. Neither is a list of species occurring at JNP for comparison.

The list of plant species provided for each habitat suggests the presence of crop wild relatives in the area. One species of *Cicer* was also reported from the area in the past but was never found. It is surprising that no effort has been made to compile a list of crop wild relatives (and other economically important plant species in the area) and suggest measures to mitigate the impact of the project on these species.

As *P. porphyrantha* is not spontaneously found in the JNP, the conditions may not be suitable for the species. A statement such as « Research is ongoing on its ecology and growing conditions as outlined in the Species Action Plan, together with research on restoration techniques and searches for other populations in Armenia » cannot be considered valid for the JNP.

Figure 8 displays the distribution of *P. porphyrantha*; such a map would have been useful in the baseline and impacts sections and should have been developed for key species of concern.

Reptiles

Offset cannot be limited to protection from deliberate killing of snakes (where in the report the killing of snakes was evaluated as major impactful activities).

> *« Residual impacts are likely and can be offset through protection of reptiles and their habitats within the proposed Jermuk National Park, together with local awareness-raising about conservation importance to reduce levels of deliberate killing of snakes».*

The report does not clearly demonstrate the possible Net gain on vipers within the future Jermuk National Park. No supporting elements are provided to assess the validity of this statement.

The management actions suggested for viper by using prescribed fire, has proven drastic negative results in literature (http://www.vipere-orsini.com/fr/program-life-nature).

Moreover, the current conservation status of existing population of viper in the JNP is not properly assessed to justify eventual management actions for vipers.

> *« The residual impact on regional numbers of these three species is expected to be small since ample habitat is present outside of the Project-affected area. In the longer term, residual impacts may be detected through monitoring. Positive conservation measures may be needed to compensate for reduced habitat extent and quality in the longer term and to this purpose restoration measures could be undertaken within the proposed Jermuk National Park. »*

Birds

The Eastern rock nuthatch is missing from the offset program while it should be considered as this species is a protected species and impact on its population is significant (table 6.11).

The residual impacts anticipated on the Lesser Krestrel, are probable on the only nesting colony in RA.

Therefore, the statement

> "*Residual impact from the projects are possible but would be confirmed through monitoring"* and *"No specific conservation measures are currently proposed but in theory it may be possible to extend breeding range in to JNP"*

cannot be considered satisfactory and an inclusion of the Lesser Krestrel in Offset program is required through active reintroduction program in the JNP.

The section presents some actions addressed to the "other birds" group.

> *« There are a number of actions that could be taken with respect to Project operations that might further reduce the risk of impacts to breeding birds in general ... At the moment these are presented as benefits for consideration, rather than required mitigation measures, but they may become more*

important depending on the results of the monitoring that will be ongoing during Project execution. »

This can hardly be considered in a Species Action Plan where every species has a specific ecology and consequently specific needs and cannot be grouped together, and because every possible effort could be considered. Some avoidance measures such as planning land preparation in view of the breeding seasons (cutting the bushes and earthworks would make the site inappropriate and direct destruction of nestlings (eggs and chicks) could be avoided.

Mammals

Set aside measures are suggested for the Brown Bear with no information as to their actual implementation and possible monitoring of efficiency to host the bears individuals.

> *« Surveys in 2015 confirmed the importance of the woodland north of Saravan, situated 1.5 km east of the HLF. This was used by at least 6 bears. Extending the Set-aside westwards to include this forest would make it more ecologically viable and suitable for bears. This possibility will be discussed when the boundary of the Set-aside and its proposed management are formalized with stakeholders in 2016 ".*

As long as efficiency of set aside is not proven successful, a more in-depth program of offset should be planned.

Gorayk Important Birds Area & Key Biodiversity Area

The report confirms that no direct impact is to be foreseen on the Goryak IBA while the major impact is the one related to the Lesser Krestrel colonies feeding on the area of the project.

> *« The Project will not have a direct impact on the IBA. Measures to mitigate impacts on species originating from the IBA that use the Project-affected area - particularly Lesser Kestrel - are included in Table 6.11.11. No further mitigation measures are necessary. »*

This statement is not based on solid considerations and indirect impacts on the IBA are likely to occur.

Most of the offset measures are postponed to eventual future results of monitoring of suggested mitigation measures.

Similarly, the Species Action Plans developed for *Potentilla porphyrantha* and *Ursus arctos* report:

« These have been produced for the two critical habitat species affected by the Project, Potentilla porphyrantha and Ursus arctos for which final analysis of survey data is needed before the Project mitigation strategy can be finalized. »

The ESIA reports many promises while it should document commitments; and the ESIA is supposed to be completed at date of submission and the latest statement undermines that the mitigation strategy is not yet fully developed.

The Biodiversity Offset Strategy (BOS) is missing a summary table summarizing for each receptor:

- Surface of critical habitat of this receptor and if possible number of individuals possibly affected by the project before mitigation,
- Mitigation measures
- Surface of critical habitat of this receptor and if possible number of individuals possibly affected by the project after mitigation (residual impact),
- Units lost due to the project after mitigation
- Offsetting measures
- Units gained by offsetting program
- Balance, NNL or Net Gain

2.2.4.2.3 Biodiversity Monitoring Plan (Appendix 8.12)

The Biodiversity monitoring is presented as part of the Environmental Monitoring plan (EMP), however no specific indicators for monitoring are provided for the natural habitats and biodiversity.

2.2.4.2.4 Mine closure and rehabilitation plan (Appendix 8.18)

This section is very general and in its current state is not directly implementable and operational. Actions are presented as objectives or aspirations and are built on experiments with no conclusive results. Ecological engineering techniques are not described in detail to enable proper assessment of relevance/adequacy.

The extraction of the turf, the storage as well as the propagation of *P.porphyrantha* are experimental measures and no guarantee related to the success of these interventions is provided.

It is current state, the evaluation of the applicability and adequacy of the post closure/ rehabilitation program remains uncertain.

2.3 Air Quality

2.3.1 Baseline Characterization

This part of the assignment assesses the methodology and results of the baseline conditions for air quality.

2.3.1.1 Expected Emissions Sources and Pollutants

The project consists of mining activities including blasting, loading and unloading of material, transport of material, crushing, but also the Gold processing including the auxiliary activities of electric power generation, organic liquid storage, and combustion of boilers. These activities will generate emissions into the air with the main pollutants being: CO, NOx, SO_2, TSP, PM_{10}, $PM_{2.5}$ but also some that are more specific to the gold processing like Hg, HCN, and HCl.

2.3.1.2 Air Quality Regulations

The air quality standards chosen by Lydian were those of the International Finance Corporation (IFC) (IFC, 2007). IFC adopts the World Health Organization (WHO) (2006) air quality guidelines in the absence of national air quality regulations. The IFC standards are generally the stricter in the world and are solely based on health impact without taking into consideration the socio-economic conditions of any country. The Maximum Permissible Concentrations (MPC) at the Republic of Armenia present generally higher standard values. From these IFC standards, the pollutants chosen to be monitored in order to determine the baseline are NO_2, SO_2, PM_{10}, and $PM_{2.5}$ and these are stricter than the Armenian standards. On the other hand, HCl and HCN are not considered in the WHO guidelines and Hg exhibits stricter values in the Armenian standards (Decision No 160-N of 2 February 2006) than those presented by the WHO (2000).

Moreover, the IFC indicates that emissions resulting from a project shall not contribute to more than 25% of the applicable air quality standards to allow additional, future sustainable development in the same airshed. This requirement was not considered by Lydian in the ESIA.

2.3.1.3 Meteorological Data Measurements

Meteorological data was considered for wind mainly at the Vorotan Pass from 1966 to 2013. Results show that a dominant wind comes from the East with an average wind speed of around 4 m/s. However, the dominant direction does not imply that lower wind direction frequencies cannot result in high pollutants concentrations since their dispersion is function of many other parameters like topography, land use and land cover.

2.3.1.4 Measurement Sites

Different measurement sites were chosen to monitor the concentrations of the ambient pollutants, especially at the settlements level regardless of the wind patterns: Gorayk (4.4 km south of Tigranes/Artavazdes pit), Saralanj (3.7 km west of Tigranes/Artavazdes pit), Gndevaz (1 km west of HLF), Gndevaz Livestock and Diary Farm (700 m west of truck loadout), Kechut (< 1 km).

2.3.1.5 Methods Used for the Measurement of Pollutants

For the measurement of NO_2 and SO_2, the passive sampling method was used which is acceptable (UK Environment Agency, 2011) along with the Light-scattering optical particle counter for PM_{10} and $PM_{2.5}$ which is also an acceptable method (UK Environment Agency, 2011).

The passive samplers were from Gradko and IVL known for this kind of measurements. The passive sampler traps targeted molecules which are extracted in the lab and their concentrations determined. It is generally exposed to ambient air for few weeks.

As for PM mass concentration, the Osiris Turnkey and EPAM 5000 were used for the measurements PM_{10} and $PM_{2.5}$. Osiris Turnkey is MCERTS certified (UK Environment Agency's Monitoring Certification Scheme for equipment, personnel and organisations). Osiris measures PM_{10} and $PM_{2.5}$ simultaneously while EPAM 5000 measure either PM_{10} or $PM_{2.5}$ depending on the configuration.

DustScan100 is a directional dust gauge used for directional dust monitoring and gives a qualitative assessment of fugitive „nuisanœ' dust emissions and deposition (IAQM, 2012). It is generally installed over 7 to 14 days. The surface soiling method involves the measurement of the loss of surface reflectance, expressed as Effective Area Coverage (EAC%).

The methods for the assessment of the baseline are valid and acceptable for the above-mentioned pollutants. On the other hand, since contaminants from such project like heavy metals are potentially released and since soil metal concentrations for some elements determined by Lydian were found not to be negligible, chemical speciation of aerosols at the receptors should have been conducted to evaluate the impact the project might have during operation on the change in aerosol composition, ***only if the aerosols concentrations from the project were found to have a non-negligible impact on air quality at the receptors'***. Moreover, no baseline assessment was conducted for gaseous Hg, HCN, and HCl.

2.3.1.6 Results of the NO_2 Concentrations

NO_2 sampling was conducted over 4 weeks each time in the main receptors mentioned above from September 2011 to January 2012 and from January to December 2014. Six locations were added alongside the main receptors namely AQ1 to AQ6 and monitored from August to October 2015. The locations and period are considered acceptable (UK Environment Agency, 2011).

Results reflect an average over the entire sampling period, ie. 4 weeks. The highest recorded concentration was at Gorayk in November 2011 with 12.34 $\mu g/m^3$.

No NO_2 measurements were conducted with other instruments for shorter periods, ie. 1-hr to assess the compliance with the 1-hr averaging period as per the IFC guidelines (2007). However, this is a generally acceptable approach.

If one uses the empirical relationship to estimate the highest 1-hr concentration (Ontario, 2009) as per the IFC and WHO guidelines of 200 $\mu g/m^3$, a value of around 78 $\mu g/m^3$ is determined, way below the 200 $\mu g/m^3$ limit. This shows that the conclusion drawn by Lydian that with these concentrations it is highly unlikely to exceed the 1-hr is acceptable. The results show that annual average is compliant with the IFC and WHO of 40 $\mu g/m^3$.

2.3.1.7 Results of the SO_2 Concentrations

SO_2 sampling was conducted also over 4 weeks each time in the main receptors mentioned above from September 2011 to January 2012 and from January to December 2014. Six locations were added alongside the main receptors namely AQ1 to AQ6 and monitored from August to October 2015. The locations and period are considered acceptable (UK Environment Agency, 2011).

Results reflect an average over the entire sampling period, ie. 4 weeks. The highest recorded concentration was at Saravan in December 2011 with 4.77 µg/m^3.

No SO_2 measurements were conducted for shorter periods with other instruments, ie. 24-hr to assess the compliance with the 24-hr averaging period as per the IFC guidelines (2007). However, this is a generally acceptable approach.

If one uses the empirical relationship to estimate the highest 24-hr concentration (Ontario, 2009) as per the IFC and WHO guidelines of 20 µg/m^3, a value of around 12.5 µg/m^3 is determined, way below the 20 µg/m^3 limit. This shows that the conclusion drawn by Lydian that with these concentrations it is highly unlikely to exceed the 24-hr is acceptable. The results show that the 2014 monthly concentrations were also very low (<2 µg/m^3).

2.3.1.8 Results of the PM Concentrations

Dustscan samples were analyzed by DustScan in the UK. The results showed that dust deposition is low and has very limited impact.

PM_{10} and $PM_{2.5}$ were monitored with Osiris and EPAM at Gndevaz and Kechut. It is not clear why $PM_{2.5}$ was not measured along with PM_{10} or at least if measured the data should have been presented. However, conclusions reached by Lydian at the surrounding villages are acceptable and in line with the monitoring reports that followed. At AQ9 (West of Tigranes /Artavazdes) and at AQ10 (North of BRSF), results are also acceptable even though the number of samples at AQ10 is low (3 samples taken in July/August 2015) since one expects low concentrations of PM_{10} and $PM_{2.5}$.

2.3.2 Impact Assessment on Air Quality

Air quality at receptors' locations is modified through the transport of the pollutants emitted from the different project sources to these locations. It is linked to the quantity of pollutants released and the dispersion of these taking into consideration the topography that plays an important role and the meteorological parameters.

Different sources of pollutants in this project exist: the fugitive dust from the mining activity, the emissions from the road transport, the boilers emissions and the Gold ore processing including Heap Leach Facility and Adsorption-Desorption-Recovery (ADR) plant.

It is worth noting that electrical diesel generators are mentioned in the SOP for Air Quality Management and monitoring for the construction phase but these sources are not mentioned in any assessment of this section.

2.3.2.1 Fugitive Dust

The mining activities (excluding exhaust emissions from road transport) generate mainly fugitive dust but also negligible quantities of other pollutants like CO, NOx, etc. from blasting.

The sources considered in the ESIA are:

- Emissions from Overburden Removal
- Emissions from Boring / Blast Hole Drilling in Artavazdes Pit
- Emissions from Blasting in Artavazdes Pit
- Emissions from the crushing process
- Emissions from the screening process
- Emissions from Material Handling including loading and unloading of trucks
- Emissions Due to Wind Erosion of Stockpile Surfaces
- Emissions from haul roads

The pollutants considered are TSP and PM_{10}. Emission factors used in the ESIA for these pollutants are from the Australian NPI (2012) and the USEPA AP-42 as indicated in the ESIA document.

The EIA and ESIA considered only Artavazdes and according to these documents, the highest activity level (including construction and closure of mine) will take place in year 3 of the project that is when Artavazdes will be exploited. This approach is considered as a worst-case scenario and is acceptable. Moreover, the trucks that will be used for transport are solely considered in the fugitive emissions from disturbed unpaved surface, meaning that wheel loaders, etc. are not considered, however this approach is acceptable since the main emitter from the disturbance of unpaved surfaces are trucks.

Some concerns are raised in the emissions calculation: the PM_{10} emission factor for the low moisture secondary crushing operation taken from Australian NPI (2012) that is based on USEPA AP-42 chapter 11.24 is considered “0” whereas both references indicate that no data is available. Other sources should have been considered or TSP emission factor of 0.6 kg/Mg used as a worst-case scenario.

$PM_{2.5}$ was not considered in the assessment. The Australian NPI (2012) does not consider $PM_{2.5}$ in its emissions estimation techniques. As per the ESIA, the fine particles travel to distances over 1000 m and can therefore impact the human receptors. On the other hand, $PM_{2.5}$ is a regulated pollutant in the Armenian standards and the IFC guidelines, therefore it must be considered anyway.

The emission factors for $PM_{2.5}$ could not be taken from the Australian NPI (2012) but part of the above-mentioned sources have $PM_{2.5}$ emission factors in the USEPA AP-42. In addition to that, other references could have been considered like the Canadian Pits and Quarries Report guide or the Mojave Desert (2013) guidance that do have $PM_{2.5}$ emission factors.

In the EIA on the other hand, some additional sources were considered on the Crushing and sorting nodes. This increases the particles emissions by around 10%.

The impact assessment of these emissions on air quality at the receptors was conducted in the ESIA and EIA for TSP and PM10 with the same approach.

<u>*Nuisance dust:*</u>

Dust in the community is normally perceived as an accumulated deposit on surfaces such as washing, window ledges, paintwork and other light-colored horizontal surfaces, e.g. car roofs. When the rate of accumulation is sufficiently rapid to cause noticeable fouling, discoloration or staining (and thus decrease the periods between cleaning) then the dust is generally considered to be a nuisance. The point at which an individual makes a complaint regarding dust is highly subjective.

In the UK and Europe there are no definitive standards for deposited particulates, however, criteria and guidelines have been developed in many other countries. Studies undertaken in Australia, for example, have resulted in the adoption of a deposited dust criteria linked to the onset of loss of amenity of about 133 mg/m²/day, averaged over one month. In the UK, long term deposited dust nuisance criteria have been suggested for urban/semi-rural areas at, typically 200 mg/m²/day, averaged over a monthly period. The range around the globe varied from 133 to 350 mg/m²/day (Vallack and Shillito, 1998).

Customs and practice at quarries, coal, construction and demolition sites have used the figure of 200 mg/m²/day as a nuisance threshold for sites in the UK for dust deposition averaged over 1 month (IAQM, 2016).

The ESIA and the EIA proposed a model for the TSP deposition based on Arup report, Schmitz (1994) and ISO12013-1. The model is based on the decay of the different sizes of PM and their settling distance with a grid of 25 m x 25m. The levels considered in the ESIA and EIA are 133 and 350 mg/m²/day. The model is considered acceptable for TSP and shows that the impact of the deposition is negligible on the receptors.

PM_{10}:

As for the PM_{10}, the screening model AERSCREEN shows that 90% of the PM_{10} will be deposited at 500 m from the site and 99% at 1000 m. With sensitive receptors located at around 1000 m, the impact would be negligible.

In fact, the project emissions are not negligible and a conclusion giving only percentages is not reliable since the absolute concentration is needed to check whether the exceedances are expected at the settlements' locations or not.

However, in 2016, the Institute of Air Quality Management (IAQM, 2016) published the Guidance on the Assessment of Mineral Dust Impacts for Planning. It indicates that "it is commonly accepted that the greatest impacts will be within 100 m of a source and this can include both large (>30 μm) and small dust particles. The greatest potential for high rates of dust deposition and elevated PM_{10} concentrations occurs within this distance. Intermediate-sized particles (10 to 30 μm) may travel up to 400 m, with occasional elevated levels of dust deposition and PM_{10} possible. Particles less than 10μm have the potential to persist beyond 400 m but with minimal significance due to dispersion."

Moreover, the IAQM (2016) states that if no sensitive receptor is located within 1 km from the activity site, an assessment for nuisance dust and PM_{10} is screened out. This is in agreement with the ESIA and EIA conclusions on this matter.

On the other hand, the guidance does not provide a clear position as per the $PM_{2.5}$. Therefore, proper modeling should have been conducted to assess the impact of $PM_{2.5}$ especially that many parameters shall be taken into consideration like the complex wind field, the land use, and the different emissions locations.

2.3.2.2 Road Transport Combustion Emissions and their Impact

Road transport emits pollutants from the haul road and from the combustion of fuel. Fugitive emissions from haul roads were considered in paragraph 2.3.2.1 and showed that its impact is generally limited. This paragraph will consider the fuel combustion emissions from road transport.

The EIA presented the exhaust emissions of the different vehicles in the project and the impact assessment while the ESIA presented only the impact assessment.

The EIA presented only the total quantity of diesel expected to be used within a year and the emission factors adopted for the calculation of emissions without stating their reference. The emission factors were compared to the off-road values of the EMEP/EEA 2016 guidebook (EMEP/EEA, 2016) and were found to be higher which gives credibility to the emission factors values presented.

Then, the assessment is based on the UK Design Manual for Roads and Bridges (DMRB Volume 11, section 3, Part 1, HA 207/07) which indicates that receptors within 200 m from the road shall be considered in the assessment. Beyond that, impact is negligible.

Indeed, since all settlements are beyond 200 m, the impact of the combustion of fuel from road transport is considered negligible.

2.3.2.3 Boilers Emissions

Boilers are used in the project for the oven, the kiln but also the heating of the buildings.

The EIA presented the exhaust emissions of CO and NOx only from the combustion of natural gas. Neither PM nor SO_2 were considered even though their emissions are negligible.

The method used for the emissions calculation in the EIA is the one approved by the N268 A ordinance of the minister on 23 October 2012. The emission factors used are higher than the ones from the EMEP/EEA guidebook (2016). The difference is acceptable.

The assessment was considered by modelling using the Raduga model as described in paragraph 2.3.2.5.

2.3.2.4 Gold Ore Processing Emissions

The Gold ore processing exhibits different steps and a variety of techniques. At most facilities, the core step is extracting the gold from the crushed ore using cyanide and carbon adsorption.

The EIA indicated that based on the experience of international experts, the maximum percentage of emitted pollutants in an ADR plant is 0.5% of the input quantity while considering Cyanide and Hydrochloric acid only with an annual demand of 1000 tons and 505 tons respectively. On the other hand, the ESIA indicates that mercury emissions are to be mitigated.

The Australian NPI (2006) for Gold Processing presents a methodology for the estimation of the emissions from Gold ore processing based mainly on a mass balance approach. This includes the leaching and adsorption processes. The main potential emissions to air are HCN, and metals like Hg. Volatilisation is expected to be the most significant cyanide emission pathway from HLF but there is no reliable method for estimating emissions of cyanide because its pathway cannot be distinguished from other fates such as natural decomposition (Australian NPI, 2006). This mass balance approach needs very good knowledge of the process parameters to be implemented since for instance, a small variation of pH will affect significantly the emissions of HCN at the adsorption process. On the other hand, the Australian NPI (2006) considers that approximately 1% of the total cyanide added to the leach circuit is lost through HCN volatilization to the air from the leach/adsorption train. This is for example a deviation of what the EIA considered to be the maximum percentage which is 0.5%.

Another example that illustrates the complexity considered in the Australian NPI manual (2006) results in around 7% of cyanide input in the circuit in terms of HCN emissions through the different pathways of volatilisation at the leaching/adsorption steps but also the tailings storage facilities. Moreover, SGS application of the SART process to heap leaching of gold-copper ores at Maricunga in Chile considers 5% volatilization for HCN. This is to say that the emissions will be best estimated by the manufacturer of the process taking into account the right flow diagram tailored to the case of Amulsar project, the process type, and the different parameters' values that are designed for this Amulsar project.

In the EIA, HCN and HCl were considered to be mitigated with a water scrubber at 86% efficiency.

In addition to that, the US EPA 40 CFR Parts 9 and 63 related to the emissions of Hazardous Air Pollutants in Gold Mine Ore Processing published in 2011 considers mercury one of the main pollutants from such process and established emission standards to it.

It was only mentioned in the ESIA that Hg concentrations in the ore were at a maximum of 0.05 g/t and that since Hg was detected on the loaded carbon columns in leach tests, a potential exists for the volatilization of mercury.

However, since no local emission standards exist for this type of industry and since HCN, Hg, and HCl have local air quality standards, modeling should be conducted to assess the emissions allowed to be released (c.a. determination of the emission limit value) in order not to breach the air quality standards taking into consideration the background concentrations for these pollutants.

The assessment was considered by modelling only HCN and HCl using the Raduga model as described in paragraph 2.3.2.5. No modelling was considered for Hg.

2.3.2.5 Modeling of the Emissions Released by the Boilers and Gold Ore Processing

The modeling exercise using Raduga model was conducted for CO and NOx from the boilers and HCN and HCl from the ADR plant, and only in the EIA.

No documentation was found or provided for Raduga model to assess its adequacy for Amulsar case. It is the regulatory model in the Republic of Armenia. What can be indicated based on the input file provided:

- Raduga is only a screening model
- It is a Gaussian model
- It does not take into account building downwash

- It only gives the highest concentration calculated
- It has a simple coefficient to account for topography
- It does not include a complete terrain module
- It does not take into account observed meteorological data hourly to assess the resulting concentrations
- It calculates wind directions for every 10-degree sector
- Values calculated are 1-hour average
- It cannot handle complex wind field

In summary, the model is not adequate for this assessment even though it is requested in the Republic of Armenia.

When the model was run, the resulting concentrations were not added to the background values to assess the breach of the local air quality standards.

2.3.3 Mitigation Measures

The EIA and ESIA presented both the same mitigation measures and they are all relevant but their effectiveness in ensuring standards are not breached is uncertain given the identified deficiencies in the baseline and impact assessment. Some measures can be added to further minimize the impact:

- Use of high screens on roads and where relevant (next to stockpiles for example) as barriers to supplement the dust suppression. These can be added on one side or both sides of the roads depending on the location.
- Watering of the soil before blasting and the ore before loading into the trucks
- Trucks should be covered to minimize the wind erosion even though at low vehicle speed
- Use more efficient control equipment or increase the efficiency of planned control equipment on stationary sources especially the ADR plant where needed: a scrubber is already mentioned in the EIA to be installed for HCN and HCl but its efficiency shall be compared to the needed one so that the project complies with the air quality standards and the specifications shall be amended in case compliance is not attained (ex. addition of alkali solution concentrations, etc.), a retort furnace is also planned to be installed and a quantity of less than 60 kg of Hg is foreseen to be collected but the efficiency shall also be checked in a way to ensure compliance with the air quality standards and the specifications shall be amended in case compliance is not attained (ex. Use of scrubbers, activated carbon filters, etc.).

2.3.4 Environmental Monitoring Program

The proposed monitoring strategy considers a visual inspection by trained environmental staff, an intermittent monitoring of the flue gas emitted by the processing plant, the continuation of the measurements of NO_2 and SO_2 through passive samplers with a sampling time of 4 weeks, the continuation of the measurements of nuisance dust with DustScan 100 with a sampling time of 1 month, the addition of Frisbee pad to monitor deposition of nuisance dust with a sampling period of 1 month, the Osiris Turkey and EPAM 5000 for the measurement of $PM_{2.5}$ and PM_{10} will be rotated over different locations.

The monitoring plan presented by Lydian for air quality is relevant and acceptable but shall be augmented to include the following based on the assessment conducted above:

- Measurement of mercury at the settlements locations to be able to assess the ADR emissions impact taking into account the background concentrations and the national air quality standards. For the gaseous mercury: 4-week measurements shall be conducted every year over 2 consecutive months in winter and 2 consecutive months in summer. The method shall be in accordance with the latest EN 15852 Ambient air quality - Standard method for the determination of total gaseous mercury. For the particulate phase: 24-hour measurements shall be conducted once per week concurrently with the Hg gaseous measurements over 2 consecutive months in winter and 2 consecutive months in summer. The method used shall be in accordance with the latest EN 12341 and EN 14902.
- Continuous emission measurement of mercury at the stack of the ADR in case the emissions are above 50% from the emission limit value that will be determined based on the modeling to ensure low levels of mercury are compliant with the national air quality standards at the settlements' locations or only twice per year in case the emissions are below 50% of the emission limit value.
- Measurement of HCN, and HCl at the settlements locations to be able to assess the ADR emissions impact taking into account the background concentrations and the national air quality standards. Measurements shall be conducted during summer and winter according to international guidance, ex. UK Environment Agency (2011) Technical guidance note M8, Monitoring Ambient Air Version 2.
- Measurement of HCN, and HCl at the stack of the ADR only twice per year to ensure their compliance with the emission limit value determined for these based on the modeling exercise.
- Setting of the trigger value for deposition of nuisance dust for the Frisbee instrument at maximum of 200 mg/m²/day.
- Measurements for the EMP shall be carried out at the locations already considered for the baseline. As for the Frisbee and DustScan 100, they shall be co-located.
- Maintain measurement of meteorological parameters at PMS and BRSF stations.

3.0 Summary, Conclusions and Data Gaps

3.1 Water and Geology - Baseline Characterization

3.1.1 Geology

The baseline characterization of the geology of the Project study area is data deficient, and the interpretation and conceptualization of the geology across the area is too simplistic. Detailed surface geologic mapping was focused on the Amulsar Mountain ridge. Fault and fracture mapping throughout the rest of the study area was not conducted. Faults may be barriers and/or conduits of groundwater flow throughout the area.

The Amulsar Mine facilities are not entirely within the Amulsar Tectonic Block (ATB). The Tigranes/Artavazdes pit area and at least part of the Erato pit are south of the Agarakadzor Fault, the southern boundary of the ATB. Part of the Kechut Reservoir is within the ATB. The Zirak Fault appears to dissect the BRSF footprint, indicating that part of the BRSF is north/northeast of the ATB. The Zirak Fault and the Agarakadzor Fault are potential conduits of groundwater flow to the major rivers. These faults also represent potential seismic hazards. The ATB does not isolate potential Project impacts from the environment. Potential seepage to groundwater from the part of the BRSF north of the Zirak Fault could result in contaminated groundwater potentially reaching the Madikenc springs. Contaminated groundwater beneath the mine pits could potentially flow to and reach the Darb and Vorotan Rivers. The extent of the impacts to groundwater cannot be determined based on available information.

The seismic hazard risk is high for the Project Area. The seismic hazards assessment is generally thorough and conservative. However, the bounding faults of the ATB block were not considered in the assessment. If displacement occurs along major active faults in the vicinity of the Project Area, including the PSSF5a that potentially underlies the Vorotan River valley, movement could potentially occur along other faults in the Project area, including the Zirak Fault under the BRSF and the Agarakadzor Fault passing through the pit areas.

Even with part of the BRSF being north of the Zirak Fault, contaminated Amulsar Mine water will not impact the Jermuk springs. Surface water and groundwater moving northward from the BRSF follow northwest trajectories toward the Arpa River and Kechut Reservoir. Jermuk is at least 1,000 m higher than the Kechut Reservoir. The Arpa River flows southward from Jermuk. Groundwater potentials decrease along the river valley in the direction of river flow. Furthermore, there is a northeast-oriented tributary to the Arpa River between Jermuk and the Project Facilities, which is a probable hydraulic boundary. Finally, Jermuk is northwest of the trace of the Kechut fault, which may also be a barrier to groundwater flow.

3.1.2 Geochemistry

The broad categories of Upper Volcanics (VC) and Lower Volcanics (LV) are inadequate for acid rock drainage (ARD) characterization. These categories encompass a range of rock sub-types that are not defined as geochemical test units for specific characterization, resulting in insufficient characterization of each rock sub-type and the ARD potential of the rocks as a whole. Likewise, ore and colluvium may be insufficiently characterized. Acid-base accounting (ABA) and classification of the tested samples are incomplete, and maximum potential acidity (AP) is incorrectly calculated. The LV and at least part of the VC are potentially acid generating (PAG). The results of the characterization should be viewed with caution. The characterization was poorly planned and coordinated. The leachate from the Site 27 Soviet era waste pile has a pH of 3.3 and high acidity. These data are a clear indicator of the potential for ARD from the Amulsar Mine.

Subsequent to the characterization, an ARD block model was developed to determine the quantity of AP waste and its distribution. The model incorporates subdivision of LV based on the percentage of total sulfur. All VC is still considered non-PAG rock. Previously, all LV was assumed to be PAG and managed the same. The model is generally based on the conservative assumption that total sulfur is a proxy for sulfide sulfur and that total sulfur greater than 2 percent is strongly acid generating. Although this approach does not rectify the deficiencies in characterization, it improves ARD management of LV rock.

Bucket testing was initiated October 2017. A generally good correspondence is observed between ABA and bucket test results, with all 11 LV samples having pyritic sulfur greater than 4% producing pH less than 4. Lower pyritic sulfur percentages produced a higher pH range of 4.5 to 6.0. One of the VC samples attained a pH as low as 4.0 in May 2018, and two other VC samples generally show pH ranges from 4.5 to 6.0. The VC sample that produced pH as low as 4.0 (4.6 – 5.75 in May and June) has 0.13% pyritic sulfur. These results reinforce the need for sub-types of rocks (geochemical test units) and that VC has potential for acid generation even at the lower end of the pyritic sulfur range identified in the original ABA testing (VC pyritic sulfur up to and more than 5%). The oxidation observed in the core boxes provides an indication of the rapidity of acid generation (drilling dates 2010 – 2012).

ARD with pH in the range of 4 – 5 cannot be dismissed as unproblematic. Acid contributes to the rate of chemical weathering of rock, which contributes to accelerated physical weathering of the rock. Accelerated weathering contributes to the rate of exposure of more pyrite in all the rock types at Amulsar. With enough pyrite exposed, very low pH solutions develop that mobilize metals, as observed in the HC tests.

The ESIA discussion of ARD geochemistry is misleading because the ARD Management Plan:

- Ignores the importance of ferrous iron oxidation in generating acid and solids (metals).
- Postulates that the reaction of pyrite by ferric iron dominates the oxidation of pyrite, when in fact the ferric iron oxidation is just one of the two pathways for pyrite to be oxidized, and the two pathways cannot be distinguished based on the products generated.
- Postulates that there is some “natural suppression agent” inhibiting the oxidation of pyrite in the LV ores, when in fact there is no evidence for some suppression agent other than the slow reaction of pyrite. There is no evidence the Amulsar rocks have natural resistance to ferric iron oxidation of pyrite and ARD generation. Given the ample evidence of ARD generation in the area (the low pH springs and the waste from the old Soviet era mine), pyrite in these rocks is evidently susceptible to oxidation and generating ARD.
- Underestimates ARD generation, and corresponding water quality and environmental impacts and water treatment requirements.

3.1.3 Water Resources

Five hydrogeologic units were delineated in the groundwater study area (GSA), which is appropriately defined. The structural control of the boundary rivers ensures that flow and transport from the GSA do not traverse these hydraulic boundaries. However, the hydraulic properties of the units are inadequately characterized by a limited distribution of hydraulic tests across the GSA and a complete lack of pumping tests. Fractured rock has extremely heterogeneous and anisotropic hydraulic properties, which are dependent on rock type, fractures, and stratification (which are variable across the GSA) and proximity to structures. Only long duration pumping tests in the various hydrogeologic units at a variety of key locations can provide a good indication of the bulk hydraulic conductivity of fractured rock and the influence of structures. The water balance for the GSA, estimates of solute transport velocities, and assessment of potential impacts are dependent on good hydraulic characterization. These important objectives can only be attained with a well-constrained numerical groundwater model in this type of geologic setting.

Baseline data are lacking for many springs in the GSA. The flow rate at a number of springs in the vicinity of Kechut were not measured. In the south of the GSA, flow was not measured at the Pluskandyal springs or other community springs southeast of Ughezdor. The ESIA states that several potentially significant springs were not visited. There is a large number of springs in the GSA, especially in the vicinity of the Amulsar Mountain ridge. Given the importance of springs to the local communities and the potential for impacts to the springs from the mine pits, the springs flow characterization is inadequate.

The ESIA concludes that groundwater recharge ranges from 200 to 250 mm/year across much of the GSA, with the greatest rates of infiltration occurring at the higher elevations. This conclusion is subjective. A wide range of recharge rates was calculated from various approaches, demonstrating considerable uncertainty in the estimates. Recharge rates based only on flow of the major rivers are among the higher values of the estimates, ranging from 244 mm/year to 460 mm/year. The recharge rate is highly variable across the GSA.

The continuous flow monitoring stations established by the Project on the Arpa, Darb, and Vorotan Rivers are generally adequate. A couple of apparent deficiencies in continuous flow monitoring are in the vicinity of Vorotan Pass. A station at the bend on the upper Darb River, where the course changes from northward to northwestward, would determine whether flow is perennial or ephemeral in that location (given the importance to groundwater flow modeling). Likewise, a station on the east side of Vorotan Pass on the upper reach of the Porsughlu River flowing into Spandaryan Reservoir would serve the same purpose. A station should also be added to the stream below Benik's Pond to monitor potential effects of the Tigranes-Artavasdes pit.

The ESIA does not provide an explanation for the hiatus in continuous flow monitoring between May and December 2013. Termination of the continuous discharge monitoring after May 2014 is questionable. Good characterization of baseflow is necessary to understand the groundwater balance and to demonstrate that the Amulsar Mine is not impacting the environment.

Major ion characteristics of Jermuk geothermal water samples are completely distinct from all other sampling locations. The Jermuk and other geothermal waters have enriched carbon isotopic signatures ($\delta^{13}C$), in contrast to Amulsar Mountain springs and groundwater, surface water, and precipitation that have depleted ratios. The geothermal waters also have significantly enriched sulfur isotopic signatures ($\delta^{34}S$) (vs distinctly less enriched surface waters and depleted signatures in Amulsar Mountain groundwater and springs). Oxygen and hydrogen isotopic ratios of the geothermal waters are lower to much lower than those in GSA surface waters, springs, and groundwaters. These data indicate the source of the geothermal springs is old meteoric water that precipitated at historically lower temperatures (potentially Pleistocene age) than the Present. The data for the geothermal springs are consistent with completely separate sources, flow paths, and timeframes. Sulfur and strontium isotopic data support the interpretation of long, deep flow paths that pass through mafic rocks with enriched $\delta^{34}S$ and lower strontium isotopic signatures than more differentiated rock types like andesite.

The isotopic signatures of $\delta^{13}C$ and $\delta^{34}S$ for Amulsar Mountain groundwater and springs reflect considerably depleted isotopes relative to the Spandaryan-Kechut tunnel outfall. Oxygen and deuterium isotopes of the tunnel outfall are depleted relative to Amulsar Mountain springs and groundwater. This difference suggests the outfall water is entering the tunnel after a moderately long flow path (aged groundwater that originated at lower temperature). The strontium isotopic ratio ($^{87}Sr/^{86}Sr$) of the outfall is also lower than the Amulsar Mountain groundwater data, suggesting significant tunnel ingress is not occurring west of the mountain ridge. Isotopic data are lacking for the basaltic rocks to the north, but the low strontium isotopic signatures and relatively high/enriched $\delta^{34}S$ of the outfall suggest groundwater flow through mafic rocks. The outfall data suggest the relatively high sulfate concentration, the distinctly less depleted $\delta^{13}C$ (relative to Amulsar Mountain), the more depleted $\delta^{18}O$ and $\delta^{2}H$, low$^{87}Sr/^{86}Sr$, and the enriched $\delta^{34}S$ of the outfall are all consistent with the majority of the tunnel ingress occurring from the basaltic rocks to the north. This interpretation is consistent with shallower groundwater as the Kechut Reservoir is approached, with greater potential for the tunnel to intersect groundwater.

A surface water quality monitoring location should be included on the main tributary of the Darb River downstream of station AW006, before the confluence with the Darb River or downstream of the tributary on the Darb River, to better assess the Mine impacts on surface water quality.

Few springs around Amulsar Mountain and the BRSF are monitored. Given the importance of springs to livestock and the large number of springs that should be monitored, increasing this number would offset the need for many additional groundwater quality monitoring wells. Assuming many more springs are added to the groundwater monitoring program, only a few more groundwater monitoring wells would be necessary, located north-northwest of the BRSF, southwest of the Arshak pit, and east of the Tigranes-Artavasdes pit.

Baseline groundwater quality data for springs and wells are deficient. Likewise, baseline surface water quality data are far from sufficient. For comparison of future concentrations, meaningful statistics are necessary, requiring 30 to 50 data points for each analyte at each monitoring station.

3.2 Groundwater Flow and Solute Transport Modeling

The water fluxes from the pit seepage sub-model are incorrect. The major issue is too much evaporation from exposed rock and loose rock backfill (with no soil cover). Use of these fluxes in the regional groundwater flow model results in incorrect assessments of impacts to groundwater levels and springs. Furthermore, solute transport simulations would severely underestimate potential impacts to groundwater and springs from ARD.

The BRSF runoff and seepage sub-models have the same excessive evaporation problem as simulated for the pit backfill. The evaporation is inconsistent with coarse texture and high permeability of the exposed loose waste rock. The calculated volumetric fluxes that report to the base of the BRSF are greatly underestimated. Underestimated water fluxes translate to underestimated ARD mass fluxes, overestimated makeup water volume, and underestimated PTS influent volume, potentially delaying the timing when the PTS is required (i.e., water treatment will be required prior to year 5 estimated in the ESIA).

An analytical solution was used to assess the potential impacts to groundwater and surface water that could result from leakage through the membrane liners of the heap leach pad and pregnant solution pond during operations through post-closure. The application of the model to simulate transport in the saturated zone is questionable, especially with the existence of a numerical groundwater flow model. The source term for transport is poorly constrained. Simulated transport species omit chloride, the most mobile solute in groundwater. Furthermore, selenium should be included in transport simulations due to the detrimental impacts of this element to fish.

A three-dimensional groundwater flow model was constructed for the GSA. The model is inadequate due to incorrect specification of boundary conditions, insufficient and uniform recharge, oversimplification of geologic structure, homogeneous, too low, and poorly-constrained hydraulic conductivities, and a poor calibration for the intended predictive usage. The simplistic numerical representation of the subsurface in the model is inadequate for making the quantitative predictions that were performed, including estimates of pit inflow. The model does not correctly represent the water balance of the GSA. Less water is moving through the simulated rocks than the actual quantity, and the simulated rates of advective flow and transport (in the particle tracking simulations) are too low. A significant omission of the modeling is the performance of solute transport simulations for predicting chemical impacts to groundwater and surface water quality. Proper assessment of potential impacts to the environment and evaluation of uncertainty cannot be performed without a numerical model of the GSA that is adequately representative of the complex subsurface and that is hydraulically well-constrained.

3.3 Water Quality and Water Resources Impacts Assessment

Overall, the water quality modeling and solute transport model simulations are poor and deficient and conclusions made based on these simulations are unreliable.

The post-closure impacts analysis for the BRSF is flawed due to underestimated potential mass loading to groundwater. The simulated pH of the leachate is 3.0, similar to Site 27 waste rock leachate. Most of the simulated concentrations are much greater than the observed concentrations, which is consistent with a much longer vertical flow path than the existing waste piles. However, the simulated iron concentration is only 0.5 mg/L, compared to 3.2 mg/L in the Site 27 leachate, which has a similar pH of 3.3. This difference is indicative of inappropriate specification of iron phases in the equilibrium modeling. An assessment of impacts to groundwater was not performed, and transport was not simulated because the ESIA/EIA incorrectly concludes that no contaminated water will reach the groundwater.

The post-closure impacts analysis of the HLF suffers from inappropriate source concentrations for the solute transport modeling. Furthermore, the transport assessment does not integrate potential impacts to groundwater from the BRSF and the mine pits.

The simulated pit runoff water quality is questionable due to the reliance on: 1) a non-conservative assumption of 40% of precipitation on the pit walls reporting to the sumps, and 2) simulated solid phase precipitation of copper oxides and iron-bearing phases with slow growth kinetics at surface temperatures. The runoff water quality has extremely low iron concentrations that are inconsistent with leachate from existing waste rock piles. The runoff is pumped from the pits, and this questionable water quality is assumed to report to the PTS.

The water quality modeling of seepage through the Tigranes-Artavasdes and Arshak pits suffers from similar procedural problems as the pit runoff modeling. The leachate bears little similarity to Site 27 waste rock leachate, which has a similar pH to the simulated leachate. Simulated iron and copper concentrations are extremely low.

The geochemical modeling of the water quality of post-closure seepage from the partially-backfilled Erato pit appears to be the most defensible of the geochemical models with respect to current, accepted methods, but there are some important concerns. Unclear is how a water balance model based on a seasonal pit lake (with water surface evaporation) with no backfill was adapted for use with backfill. Uncertainty of results was evaluated with a range of inputs. The simulated iron concentrations are low compared to Site 27 waste rock leachate, which has a similar pH. Otherwise, the simulated concentration ranges of other solutes encompass the concentrations in the Sites 13 and 27 waste rock leachates and mine portal drainage.

The post-closure solute transport simulations underestimate potential impacts to groundwater and surface water. The solute transport scenario and the local impacts scenario based on mixing are not conservative, with source concentrations determined by geochemical modeling that are too low. Loading rates to groundwater are also underestimated due to seepage rates from the pits that are too low, and the predicted concentrations do not include potential effects of the BRSF and HLF. The screening level spreadsheet (analytical) model approach used for solute transport is inappropriate for a project of this scope, extent, and complexity in such an environmentally-sensitive area. Predictions of impacts require an integrated approach that includes loading of constituents to groundwater and surface waters from all potential sources. The existing regional groundwater flow model should be revised and extended for transport simulations.

The Project water balance modeling results for the 95% probability of exceedance (covering wide uncertainty) suggest sufficient capacities are calculated for pit pumping and pond sizing. Uncertainty could be reduced with improved inputs for some questionable parameter values.

The baseline studies and the evaluations for the ESIA are poorly planned and poorly integrated, rushed, and incomplete. For example, impacts assessment modeling was performed before studies were complete or other modeling was performed on which inputs for a model are dependent (*e.g.,* unsaturated flow modeling of infiltration through the post-closure cover was not complete at the time of the HLF assessment). The mine closure plan was not complete at the time of the HLF assessment. Studies and planning were still being performed at the writing of the current version of the ESIA. Although the SWWB was updated, the models for fate and transport simulations and impacts assessments were not revised or updated.

Surface water and groundwater monitoring data provided by the MNP (SNCO, 2019) indicate the presence of a localized, transient spike in nitrate concentrations in water samples from Spring 529, located near Spandaryan reservoir. Given the absence of a corresponding trend in other constituents and in water quality in the Arpa River, the transient and localized nitrate trend cannot be attributed with a reasonable degree of scientific certainty to the initial Mine construction activities. Accordingly, no discernable impacts onto surface water or groundwater due to initial mine construction activities could be inferred.

3.4 Water and Geology - Mitigation Measures

The main sources of potential environmental impacts to surface water and groundwater are the BRSF, the HLF, the Mine pits, and all associated infrastructure for collecting, channeling, impounding, and treating contact water.

Generally, the design concepts used in the Amulsar ESIA/EIA for development of mitigation measures are reasonable and appropriate (e.g., low permeability liners, encapsulation, capping, drainage, and leachate treatment). However, a number of the measures and plans, are partial, not-sufficiently protective, and/or unreliable with a high degree of uncertainty, particularly due to deficient and questionable data, models, model simulations, design bases, and/or assessment.

3.4.1 Mine Pits

While the mine is operating, some of the runoff water will be collected and diverted to the HLF. Some of the runoff water accumulating in the pits and potentially generating ARD will infiltrate to groundwater through rock fractures. Post-closure mitigation measures are partial backfilling the Tigranes-Artavasdes and Erato pits and emplacement of an ET soil cover on backfill. Backfilling mitigates the negative effects of pit seepage to groundwater. The ET soil cover on the Tigranes-Artavasdes backfill will mitigate generation of ARD from backfill and seepage of ARD-impacted water to groundwater (by limiting water infiltration and air ingress). The PAG waste rock will have voids among rock particles/fragments that will permit infiltration. Some ARD may still occur. Runoff will also collect in the pits. The Arshak pit will not be backfilled and will seasonally accumulate runoff in the base of the pit.

There is a clear potential for contamination of groundwater by ARD-impacted pit seepage water. This contamination would particularly affect nearby springs, which are important for local livestock and wildlife. The Amulsar rocks have essentially no pH buffering capacity. With distance from the mine pits, some natural attenuation of chemical concentrations via dilution will occur before the contaminated groundwater reaches other environmental receptors (streams and rivers).

There are no contingency plans to address or mitigate groundwater contamination originating from the pits during the operation or closure phases beyond monitoring, for which no details are provided.

3.4.2 BRSF

While the mine is operating, the PAG waste rock (LV) will be placed on a non-PAG (VC) rock drainage layer, which will be underlain by compacted native clayey soil or a constructed clay liner. The design concept of using non-PAG drainage layer at the base of the waste rock pile and an underlying low permeability liner to mitigate infiltration to groundwater is adequate. However, the liner design criteria (*i.e.,* relatively small thickness, relatively high hydraulic conductivity, limited hydraulic conductivity testing, and compaction using vehicle traffic) are questionable and raise concerns about the long term performance, integrity, and protectiveness of the liner.

Other mitigation measures include sub-grade drains in perennial stream channels beneath the BRSF, a toe pond to collect contact water, and runoff diversion channels. Additional closure mitigation measures include capping the PAG waste rock with non-PAG VC waste rock, an ET soil cover, and directing contact water to the PTS.

The ET soil cover will mitigate generation of ARD from PAG waste rock and seepage of ARD-impacted water to groundwater (by limiting water infiltration and air ingress). The PAG waste rock will have voids among rock particles/fragments that will permit infiltration. Some ARD may occur.

3.4.3 HLF

The mitigation measures included in the design of the HLF are generally appropriate. The design includes a composite geomembrane-soil liner system and a drainage collection system above the liner that directs the PLS to the process pond. Diversion embankments and channels will be constructed upslope of the HLF to divert runoff away from the pad and collection ponds. Underdrains will be constructed in existing drainages and seeps within the leach pad and collection pond footprints. The leach pad will have a toe berm and perimeter berms to prevent overflow. The solution and storm flows will be routed to the process pond.

The process pond will have a composite double geomembrane-soil liner system and a leak collection and recovery system. The storm water ponds will have a composite geomembrane-soil liner. Closure measures for the HLF include an ET soil cover.

3.4.4 Contact Water Treatment Systems

The ESIA focuses on and proposes PTS for Mine contact water. Two PTS are proposed - one for the heap pile leachate after mine closure and the second for the BRSF leachate both during and after closure of mine operation. The heap pile leachate treatment system is addressed in a separate section, while the discussion below focuses on the PTS for the BRSF.

The ESIA and previous ARD Management Plan (Geoteam, 2016c) state that if treatment trials indicate that PTS will not meet the discharge criteria (MAC II standards) then a conventional packaged active water treatment system will be used. There are no descriptions of the decision-making process or details about the active treatment processes or requirements. The commitment to use active treatment in case of PTS inability to meet MAC II Standards, has been omitted in the updated ARD Management Plan (GRE, 2017). Therefore, this option cannot be assessed.

3.4.4.1 ARD - BRSF

The design of the PTS for the BRSF has significant shortcomings:

- The system design using a PTS has been selected much too early in the process and does not allow for the flexibility needed to deal with such a complex and uncertain water mixture. The design is based on modelled water quality that is questionable. If the modelled water quality is not valid, then the system, if not revised to meet the actual influent quality, will likely fail and result in the release of contaminated water at concentrations above permissible criteria into the receiving surface water.

The GARD Guide (INAP, 2009) indicates active water treatment is most appropriate during mine operations. A passive system is more appropriate for treatment of water with low chemical concentrations after the mine has been closed. Since water will need to be treated during the last several (five) years of mine operation, an active system may be more appropriate and may need to be considered as an interim or supplemental measure.

- The water quality modeling has significant discrepancies and uncertainties that raise concerns about the reliability of water quality projections and about the feasibility and effectiveness of the proposed PTS, especially during Mine operation.
  - The modelled iron concentrations for influent water are much too low for natural waters, especially waters impacted by ARD.
  - The charge balance for cations and anions in the incoming water for the PTS has a large error that significantly exceeds the acceptance criterion.
  - The aluminum concentrations are too low and inconsistent in different descriptions of the incoming water for the PTS.
  - Recent updates to the site-wide water balance (SWWB) will likely impact the projected PTS influent water quality and quantity.
  - During the years of mine operation, the water coming into the PTS will contain both water from the BRSF and excess water from the pits that is not used in the heap leach operation. The influence of the pits water on the overall water quality should have been included in the geochemical model, especially with the updated SWWB.
- Ammonia in the influent will most likely be present at concentrations significantly higher than the discharge criterion/standard, but the treatment process for ammonia is not addressed except for brief, extraneous comments. Although discussed, Nitrate treatment requires further and more robust evaluation. Nitrate and ammonia are likely to be the major contaminants that require treatment while the mine is operating to ensure the effluent meets the discharge criteria and prevent contamination of the receiving surface water.

3.4.4.2 HLF

The discussion of the HLS management and treatment has two major discrepancies:

- The projected HLS quality at the end of operation, both before and after cyanide treatment is unrealistic. The water quality used for geochemical modeling comes from tests that were not designed for assessment of environmental impacts, treatment, and compliance of the influent. The water quality results have internal inconsistencies indicating that some of the results are incorrect. Further, at the end of the mine operations, the HL water will have been in circulation for ten years and will likely have elevated concentrations of soluble constituents (sodium, nitrate, chloride) added to the water from operations and elevated concentrations of trace constituents leached from the ore (sulfate, trace metals) that will require treatment prior to discharge. There is no good modeling of these concentrations to know what to treat and how to treat them.

- There is no indication of how the barren solution after the pass-through the ADR will be managed and treated (only the treatment of the rinse water is conceptually discussed). This water may be on the order of 1 million m^3 and may contain high concentrations of ions that can be difficult to treat (sodium, chloride, nitrate, etc.), and thus may impact the quality of the receiving surface water if not treated prior to discharge.

  The water coming from the HL ore pile following closure will be treated in a PTS to be designed in the future after obtaining actual water quality data. Although PTS is potentially applicable for the post-closure HLF solution and leachate, there are no plans for laboratory treatability or pilot testing to assess the feasibility and effectiveness of PTS. Also, there are no discussions of contingent or supplemental measures in case of PTS failure.

3.4.5 Natural Disasters

River flood risk is extremely low. The current design of the contact water ponds includes free-board for the 100-year, 24-hour storm. Considering effects of climate change and the high degree of uncertainty in the Project data, designing the contact water ponds and diversion systems against the 500-year, 24-hour storm event (as recommended by the Nevada Division of Environmental Protection regulations and guidance for mine closures) may be warranted.

The seismic hazard risk is high for the Project Area. In the event of an earthquake, covers on the BRSF and pit backfill could be restored. Breached liners beneath the BRSF and the HLF would require temporary or permanent relocation of the rock and spent ore. The repair of conveyance piping for contact water ponds will require partial or complete drainage of the ponds. Contingency measures to handle and treat the stored contact water will be required. The revised construction standard should be reviewed for compliance of all mining infrastructure, including the potential need for reinforcement or double containment of piping. Historic landslides surrounding the Amulsar Mine should be documented in the ESIA.

The Mine pits and BRSF are within the Lake Sevan Immediate Impact Zone. Catastrophic earthquakes can cause a release of mine contact water and adversely impact groundwater and surface water within the Lake Sevan Immediate Impact Zone, particularly during the operation phase when large quantities of contact water are stored in ponds. Such releases will contaminate nearby springs and the Arpa River. The significance of the impacts on the Kechut and Vorotan Reservoirs and Darb River (and Sevan Lake) is uncertain because the models in the ESIA did not evaluate or quantify these impacts. Under certain circumstances, however, especially if releases occur post closure, such impacts can be limited due to the relatively smaller volume of contact water that will be released from the Mine compared to the significantly larger water volume in the watershed, including the Kechut and Spandaryan Reservoirs and Sevan Lake.

Due to the hydraulic and physical setting, the Mine water will not impact Jermuk springs.

3.5 Post Closure Cost

The Amulsar Mine closure cost bases and estimates are provided in Appendix 8.18 of the ESIA. The cost was reviewed for general consistency with standard practice. The cost estimates cover major rehabilitation and closure scope items. However, a number of cost items are questionable and the overall cost appears to be underestimated. Below are key concerns:

- The post closure OM&M period is limited to only five years. In the US, regulatory requirements and guides for closure indicate post closure costs, when contamination sources remain, should be estimated for a revolving 30-year period (minimum). Post closure costs should include routine OM&M and periodic replacement, maintenance and repair that will occur after 5 years, which can be significant. The reduced post closure monitoring period and the omission of the periodic replacement/maintenance costs will result in significantly underestimating the post closure costs.

  Increasing the post closure monitoring period from 5 years noted in the ESIA to the conventional 30 years, the total Mine rehabilitation and closure cost will increase from approximately $34M to approximately $70M (without other adjustments) .

- Contingency is too low at 6% and underestimates the actual Mine rehabilitation and closure cost. Cost estimation guides indicate that at this level of project development (pre-feasibility) and the high degree of uncertainty (*e.g*., unreliable data and PTS and need for additional studies, *etc.*) the contingency can exceed 20%.

  Using a more realistic contingency of 20% instead of the ESIA 6%, the total indirect cost percent would increase from 21.3% to 35.3%. Accordingly, the total Mine rehabilitation and closure cost will increase from approximately $34M (for the ESIA 6% contingency and 5-year post closure monitoring period) to approximately $78M (for 20% contingency and a 30-year post closure monitoring period) without other adjustments.

- Treatment requirements are unrealistic (actual costs will be higher) due to incorrectly assumed low leachate concentrations and mass loading and missing processes.

- Professional/technical costs (design/engineering, project management, and construction management) at approximately 3% of total construction/capital cost (on the order of $1M) are underestimated. Cost estimation guides indicate these services can exceed 15% of total construction costs for similar projects. Using 15% for these services would result in an additional increase to the Mine closure cost on the order of $4M to $5M.

- Many cost items are presented as lump sum without bases and cannot be assessed.

3.6 Environmental Monitoring Program

The Project needs to develop a comprehensive and defensible plan for future monitoring (operations, closure, and post-closure).

The number of surface water quality monitoring locations in the quarterly monitoring reports is insufficient. No locations on the Darb River or north of the Kechut Reservoir (including Jermuk) were sampled. Most locations north of the BRSF, including the stream in the vicinity of the Madikenc springs, the Spandaryan Reservoir, two locations around Gorayk, and all locations east and west of Amulsar Mountain were omitted.

The number of springs and groundwater quality monitoring locations is extremely inadequate. The sampling program is also unacceptable with respect the deficiency in baseline data.

The monitoring reports do not include potentiometric surface contour maps or contour maps of key constituents in groundwater. There are no time-concentration graphs and there is no assessment of results with respect to previous results and no discussion of analytical methods.

3.7 Water and Geology - Data Gaps

- Pumping tests to evaluate bulk hydraulic properties anisotropy, and the extent and influence of fractures and boundaries (faults and streams) with the objective to update the groundwater flow and transport models.
- Tracer tests to evaluate fracture characteristics and extent and key transport parameters and to improve the groundwater flow and solute transport models.
- Laboratory testing of surrogate rock pile materials (from existing waste rock piles) with the expected particle size distribution of pit backfill and BRSF waste rock and topsoil for saturated hydraulic conductivity, soil-drainage and relative permeability curves, and thermal properties to update the infiltration models.
- Grass leaf area index and root depth data for soil cover models.
- Better records of springs, seeps, and river flows (continuous records).
- Considerably more water quality data for statistical analyses.
- Monitoring stations at more perennial springs around Amulsar Mountain and the BRSF.
- Better recharge constraints, including continuous flow measurements on the major rivers and watershed modeling.
- Better water balance constraints in the BRSF, pit backfill, and HLF models.
- Realistic data and geochemical modeling of the range of influent concentrations coming from ARD or the blasting activities (acidity, iron, aluminum, sulfate, nitrate, and ammonia) in the water sources contributing to the influent for the BRSF PTS for the PTS design and how these concentrations will change during and after mining operations.
- Data from laboratory bench scale and field pilot testing of proposed treatment processes to demonstrate effective treatment of the range of concentrations of parameters in leachate from ARD and the blasting activities to the PTS for both the BRSF/pits and HLF.
- Chemical analysis of a bench scale pregnant leach solution that represents the effects of all processes and loading from all sources during numerous cycles of leaching.
- Isotopic data for unaltered LV and basalt across the GSA.
- Geologic data for the broader GSA.
- Surface fault and fracture mapping.
- Elevations and construction details of the Spandaryan-Kechut tunnel.
- Wells near the Spandaryan-Kechut tunnel to determine groundwater levels with respect to the tunnel and the water quality that may be entering the tunnel, now and in the future, to improve understanding of groundwater flow and the site model.

- Flow data for upper reaches of the Darb River above Ughezdor and the Porsughlu River flowing into Spandaryan Reservoir.
- A surface water quality monitoring location on the main tributary of the Darb River downstream of station AW006, just before the confluence with the Darb River or just downstream of the tributary on the Darb River, to ensure all impacts from the mine pits are detectable.
- Additional deep monitoring wells north-northwest of the BRSF, southwest of the Arshak pit, and east of the Tigranes-Artavasdes pit, screened sufficiently deep to have saturated rock adjacent the well screens the entire year.
- Flow measurements at the Pluskandyal springs and the other community springs southeast of Ughezdor.
- Flow measurements for the two springs on the south side of the Porsughlu River that supply water to Gorayk.
- Flow measurements at the springs around Benik Pond
- Multiple samples and tests of well-defined geochemical test units based on mineralogy; also a range of spent ore types/textures.
- Better analyses of full sets of anions and cations in solutions used in geochemical modeling to ensure charge balance.
- Field assessments of various potential fault alignments of the ATB and their potential impacts on water resources.

3.8 Biodiversity

This ESIA provides an opportunity for the Republic of Armenia to assess biodiversity and its status in the Amulsar region. This is especially the case for the Brown bear (*Ursus arctos)* and *Potentilla porphyrantha*, as it triggered international and national focus on key species of concern generating extensive field derived data.

ESIA/EIA Sections on Biodiversity were evaluated in view of best practice recommended in terms of ESIA development and in particular the importance of functional ecology approach in this type of evaluation.

No breach to any national or international regulations or recommendations are to be noted.

Observations highlighted throughout the assessment and in this conclusion are mainly intended for use in the event of an update or improvement of the ESIA especially that, given the amount of efforts invested to develop this ESIA, the methodology could have been improved to cover ecological functionalities and a more exhaustive assessment.

No violation is to be reported. The report had focused and provided quality and exhaustive information on two flag species which are the *Ursus artos* and *Potentially porphyrantha* while addressing other species in a less exhaustive and sometime insufficient manner.

Main concerns are:

- Some data gaps or over simplification of data in the Baseline that have led to an underestimation of the impacts on key receptors which in turn lead to inappropriate mitigation measures and therefore a suggestion of offset program that does not enable to reach the No Net Loss neither the net gain claimed in the ESIA and required by IFC PS6 and EBRD PR6.

In particular:

1. Quantified evaluation of impacts (and ideally geolocation) deserves more clarification to understand how the magnitude of impacts has been estimated and reported
2. Some key species are not properly addressed in the impact evaluation and properly considered in the mitigation measures section. This is the case for:
    a. Ursini viper group
    b. Eastern rock nuthatch
    c. “Other birds” group are considered as a group in the SAP while every species has specific ecological features and consequently specific needs.
3. Off set program reports NNL and Net gain while
    a. Measures of Potentilla are still experimental, results need to be monitored and offset program design is recommended.

It was suggested to initiate a conservation program on other populations of *P. porphyrantha* in Armenia and response was that other population reported in the literature were not found as a result of a field investigation. Should this statement be confirmed, the Population of *P. prophyrantha* located in the Amulsar mountain becomes the ONLY viable population in RA which increases the need to properly mitigate the impacts.

    b. Eastern rock nuthatch and Lesser Krestrel are not considered in the offset
    c. Ursini vipers group is not considered
    d. Brown bear set aside and wild life crosses being experimental measures, those should be monitored and a more in depth offset program proposed

The following comments are mainly intended to provide guidance on possible improvement on eventual future versions (if applicable):

- Provide consistent figures and non-redundant information throughout the various chapters - an effort towards harmonization of the format and the content of the various chapters.
- Present a clear methodology regarding the quantified evaluation of impacts.
- Include geolocalized maps presenting the assessment, the impacts and the importance of the direct and indirect impacts on habitats and species.
- Include a summary in the text of the various key elements when presented in appendices to improve lisibility.
- Develop clear synthesis and summary tables enabling transversal evaluation in view of ecological stakes and expected impacts to better present the information available.
- Review the methodology to cover all project area, key seasons and functional approach in addition to proper field investigation pressure in view of the large extent of the area.
- Clearly distinguish between mitigation and experimental measures and in case of non-confirmed zero residual impact, account for an appropriate offset measure.
- Avoid oversimplified conclusions especially when it comes to the NNL or Net gain claimed in the offset program.

3.9 Biodiversity – Data Gaps

The major weakness of the biodiversity assessment lies in the absence of geolocated information and the absence of synthesis enabling the assessor to understand and assess the effective extent of project's components and their impacts on various ecological receptors.

The essential gaps needed to be fulfilled are described below.

1- Baseline data

a. Project's components vis-à-vis the ASCI, IPA, IBA, KBA, Priority areas for Conservation, and existing and planned protected areas network

b. Complete field work with adequate field intensity and methodology with sampling plan taking into account all footprint of the project for insects and reptiles

c. Habitat detailed description (ex : Potentilla), ecological functionalities of each habitat (ex : Lesser kestrel), geolocalisation of habitats (ex : specific habitat for Vipera eriwanensis, or mapping of host plant for Apollo butterfly), based on reliable methodology and field observation intensity

2- Calculations with clear reporting tables

a. Definition and geolocalisation of the project's footprint surfaces (direct impact, different levels of indirect impacts) and clear overlaps with each species habitat

b. assessment of the impacts (before mitigation and after mitigation, with synthesis tables) on the various receptors (surfaces, number of individuals when known, ecological functionalities impacted…)

3- Information

a. list of endemic plants species that occur vis-à-vis or might occur in the site (22 mentioned but not listed)

b. list of latin names of species with ethnobotanical value (provided in local names)

4- Methodology

a. Clear methodology for the evaluation of significance of impacts

b. Mitigation measures for all priority receptors

c. Monitoring program for avoided impacts

d. Anticipation of offsetting programs for priority receptors not taken into account in the current offset program (bird species such as Lesser kestrel, nuthatch, vipers…) with adequate developed monitoring programs and geo localised management measures

3.10 Air Quality

Summary and main conclusions of the assessment of air quality sections of the EIA/ESIA are:

- The regulations adopted for the assessment of impacts on air quality do not fully comply with the IFC requirements (which mandate the consideration of national standards as a priority and in their absence to adopt IFC standards) in the ESIA since Hg, HCN, and HCl are not considered in the assessment while there are national standards for these parameters that need to be complied with; furthermore these parameters were not considered in the baseline assessment.
- For the NO_2, SO_2, PM_{10}, and $PM_{2.5}$, baseline values are acceptable.
- Emissions of fugitive dust from the mining activities, namely TSP and PM_{10}, were generally calculated correctly and their impact is negligible on the settlements (from around 1 km and beyond) in line with the ESIA and EIA conclusions.
- $PM_{2.5}$ emissions were not estimated and their impact on the settlements was not assessed properly; proper modeling shall be conducted with an adequate model that takes into account the complex wind field in the area. The impact is expected to be low but needs to be assessed.
- Road transport exhaust emissions have negligible impact due to their distances from the receptors in line with what the ESIA and EIA suggest.
- Boilers emissions were assessed properly in the EIA but are not mentioned in the ESIA. These run on natural gas which emits low levels of pollutants. However, their impact was assessed in the EIA through the Raduga model which is considered not appropriate for this analysis. The impact of the boilers is not expected to be significant but a proper modeling shall demonstrate it.
- The ADR plant emissions were not estimated correctly since Hg was not considered and a solid estimation of the emissions for HCN and HCl was not made. These emissions shall be determined by the process and plant manufacturer. Afterwards, a proper modeling shall be conducted taking into account the baseline for these pollutants at the receptors' locations in order to set the emission limit values since these do not exist on the national level.
- The types of mitigation measures presented in the EIA and ESIA are generally acceptable but few were suggested to be added to decrease further the emissions from the stationary and fugitive sources. Additional assessment is needed to conclude if the performance of these mitigation measures are sufficient (i.e. air dispersion modeling, determination of the emission limit value, etc.).
- The environmental monitoring program presented in the EIA and ESIA is acceptable but is proposed to be augmented to better control and monitor the sources of pollution and their impact.

In general, no major issues were identified in a way that cannot be mitigated. Taking into account the additional mitigation measures and monitoring actions, the impact of the project related to air quality is likely to be manageable.

4.0 Responses to Specific TOR Questions

4.1 Water and Geology

This section presents responses (**bold**) to specific questions (*italic*) included in the TOR.

i. TOR Question: Are the assessments presented by Lydian in the ESIA and EIA Reports and in the appendices attached to them sufficient, qualified, scientifically justified and comprehensive, or not; did the conclusions, derive from the reliable and actual data and was the methodology developed for these conclusions comprehensive and reliable?

Response: Most tools used in the assessment are suitable and are consistent with acceptable and standard practices. However, key elements of the assessments are inadequate, deficient, and inaccurate. Baseline data deficiencies abound for geology, ARD characterization, hydrogeology, surface water and springs flow, and surface water and groundwater quality. Deficiencies led to questionable simplifications and interpretations. Models for assisting with the assessments are oversimplified, incorrectly parameterized, procedurally incorrect, poorly calibrated, and not conservative. Key data, conceptualizations, and modeling approaches are unreliable, and impacts assessments are incomplete, leading to conclusions that are unreliable with a high degree of uncertainty. Good isotopic data were acquired, from which reliable conclusions can be reached.

ii. TOR Question: Are the methods of control of production of wastewater, mine waters, presented in ESIA and EIA reports, scientifically justified and effective, or not; do they stem from the regulatory requirements and international standards?

Response: The methods of control of wastewater production and mine waters are conceptually adequate, some have been effective in previous applications, and some are partly scientifically justified (See Section 2.1.5). The methods are based on local regulatory requirements and partly conform to international standards. However, the passive treatment system chosen for the PD-8 and BRSF water is designed for water with low incoming iron and aluminum concentrations and low dissolved oxygen. The water quality modeling is insufficient to justify such a system, because higher iron or aluminum concentrations, detected during testing, could cause the system to fail. In addition, the water quality coming into the treatment system will vary at different stages in the mine life – during operation the water will have higher concentrations of nitrate and ammonia, while after the mine closes these concentrations will decrease and the focus of the treatment will be on ARD products. A single passive system is not suited for treating such changing conditions. The GARD Guide recommends that an active system be used during mining operations, while a passive system may be more suited for post-mining conditions. Finally, there is no discussion of how ammonia will be treated. The treatment system will likely need to be redesigned to fully treat the varying constituents and concentrations in the wastewater. Also, the PTS for the BRSF/Mine Pits leachate treatment may need to be implemented earlier than estimated due to questionable water balances from the BRSF and Mine pits.

Some of the mitigation measures for ARD at the pits and BRSF (see Sections 2.1.5.1 and 2.1.5.2) are partially effective.

The ARD mitigation plans do not include contingency measures for groundwater contamination originating from the pits.

iii. *TOR Question: Does the monitoring program, presented in Lydian's ESIA and EIA, include all necessary components (land, air, water, flora, fauna, etc.) of the environment and are the arrangements, foreseen by the program, sufficient in terms of the set standards, or not?*

Response: The available monitoring programs are for the pre-construction (baseline) and construction phases. The surface water and groundwater monitoring programs have all the necessary components. Augmentation of the programs with more monitoring stations is necessary, especially for springs monitoring. The number of surface water and groundwater quality samples is deficient at many existing stations. Meaningful statistics cannot be developed for reliable comparison of future water quality due to the limited number of samples. In addition, a few more monitoring wells are necessary north-northwest of the BRSF, southwest of the Arshak pit, and east of the Tigranes-Artavasdes pit to better assess the potential impacts to groundwater.

The available monitoring plans do not cover the operation and post closure phases.

iv. *TOR Question: Which risks, in particular, were not taken into account in terms of environmental security in the ESIA and EIA Reports? What dangers to the environment and to the health of the population may occur as a result of their omission? Are these possible negative consequences recoverable, or not, and if they are, what time frame and what type of financial resources would be necessary?*

Response: Known faults within the Project study area were not considered in the seismic hazards analysis. Movement on the seismically-active PSSF fault system could cause fault slip in the study area, potentially compromising the liner beneath the BRSF and the cover and destabilize the waste rock pile (Zirak Fault beneath BRSF). This fault could conduct ARD-impacted seepage water from the BRSF toward the Kechut Reservoir and/or to the Vorotan River. Fault slip on the Agarakadzor Fault passing through the vicinity of the pits and BRSF could also impact the stability and integrity of the BRSF and pit backfill and cover systems. Ground motion could also impact the stability of the HLF, liner, and cover and inflict damage on the contact water channels, ponds, and PTS, potentially resulting in releases of impacted water to surface water and groundwater.

The potential significance of fault and fracture flow in the groundwater study area was not considered in the analyses of potential impacts to the environment. Solute transport is many orders-of-magnitude faster in fractures than rock and sediment matrices, with much less attenuation. ARD-impacted groundwater could be rapidly transported to springs, streams, and rivers, potentially impacting community water supplies and livestock grazing activities.

Covers on the BRSF and pit backfill can be restored, if impaired by earthquakes. Breached liners beneath the BRSF and the HLF would be a challenging problem to address, requiring temporary or permanent relocation of the rock and spent ore. A destabilized BRSF and/or pit backfill could result in permanent loss of the non-acid generating VC layer of rock between the cover and the PAG rock. Any exposed PAG rock on pit walls or in the BRSF, HLF, or pit backfill due to earthquakes could impact the environment for hundreds, or possibly on the scale of a thousand or more years.

The concentrations of key constituents in contact water (e.g., iron, aluminum, nitrate, ammonia, and sulfate) are underestimated, which may cause the PTS to fail (unless redesigned or augmented). Such failure may result in the release of contaminants to the environment (surface water and groundwater) at concentrations exceeding RA discharge criteria/MAC standards.

Mitigation measures for the Mine pits are limited to periodic pumping during operation and backfilling and the placement of an ET soil cover post closure. Contingent and supplemental measures are necessary to mitigate ARD impacts on the groundwater quality.

v. TOR Question: Is there any interaction between Amulsar water basin, the adjacent underground and the surface water, rivers, water reservoirs, Spandaryan-Kechut water reservoir hydro-technical structure and Jermuk mineral water reservoir, or not?

Response: Groundwater flow and contaminant transport pathways between the Project Area and the Jermuk thermal springs do not exist.

Rivers and tributaries surrounding and within the Project Area are connected to groundwater. Groundwater discharges from the Project Area to springs and rivers. Releases of untreated Mine contact water can contaminate groundwater and can reach and impact surface waters. Groundwater from the Project Area also discharges to the Spandaryan-Kechut tunnel through sections of the tunnel where the walls/joints are leaky (i.e., areas of direct hydraulic connection between the groundwater and the tunnel). Isotopic data suggest most of the discharge of groundwater to the Spandaryan-Kechut tunnel occurs north of the Mine in the Cenozoic basalt, where groundwater is shallowest in the vicinity of the Arpa River and the Kechut Reservoir.

Surface water in reservoirs generally seeps to groundwater. The dam on the Arpa River causes head buildup in the Kechut reservoir and corresponding groundwater mounding, which induces downward and outward hydraulic gradients and flow. Therefore, direct discharge of groundwater to the reservoir does not occur. However, groundwater that discharges to springs, streams, and the Spandaryan-Kechut tunnel will flow into the reservoir.

If a deep aquifer underlies the volcanic rocks in the area, interaction between groundwater in the volcanic rocks of the Project Area and the deep aquifer is unlikely. Groundwater originating in the Project Area by local infiltration of

precipitation discharges to springs and the Arpa, Darb, and Vorotan Rivers and their tributaries.

vi. *TOR Question: Is the data on sulfide compounds in the rock, presented in the ESIA and EIA, calculated correctly, or not, are the control methods of the acid drainage scientifically justified, or not, can they effectively prevent acid drainage water into the environment?*

Response: The acid-generating potential of the rock was calculated incorrectly. The Modified Sobek method was used for acid-base accounting, which determines maximum potential acidity based only on sulfide sulfur. This approach is incorrect because nearly all samples from both pit areas have acidic paste pH values indicative of acidic sulfate salts (e.g., alunite and jarosite), identified in both VC and LV. The analyzed percentage of sulfate should have been included in the AP calculation. The ARD Management Plan ignores the importance of oxidation of ferrous iron (from pyrite oxidation) in generating ARD.

The methods to limit acid mine drainage are scientifically justified, but they cannot completely prevent ARD. Backfilling the mine pits above the level of a pit lake effectively prevents evapoconcentration and most acid generation in the saturated backfill. Water acts as an oxygen ingress barrier because the rate of oxygen diffusion in water is extremely low. Sulfide oxidation potential is eliminated or negligible. Evapotranspiration soil covers should limit infiltration of precipitation and ingress of oxygen to the waste rock in the BRSF and pit backfill. However, infiltration of precipitation during prolonged wet conditions and snowmelt will occur, carrying oxygenated water into the PAG rock. The layer of non-acid generating VC on the BRSF will not deflect infiltration in the PAG rock. The LV PAG rock is not an impermeable pile of fat clay. The LV waste rock will consist of blocks, chunks, and pieces of rock with a range of grain sizes. Pore space between these various rock particles will permit infiltration. Consequently, some ARD may occur. Furthermore, the mine pit walls and bottom will be exposed and will permit seepage of accumulated water into the groundwater.

The design criteria of the clay liner under the BRSF are questionable and raise concerns about the integrity and protectiveness of the liner.

vii. *TOR Question: Depending on the chemical content of the ore, the size and location of the heap leaching facilities, and the plans of the open pit exploitation and subsequent closure of the mine, which areas of the mining site are most likely going to generate acid drainage, in what volumes, and as a result of what type of geochemical processes and changes?*

Response: The largest volume of acid rock drainage will be generated in the Mine pits after closure. Exposed pit walls will remain in all three pits. The volume of ARD will be a function of precipitation and snowmelt running down the walls and through the oxidation rind. Oxidation of pyrite under moist, unsaturated conditions and secondary minerals with stored acidity will release acid and solutes to runoff. Soil covers and sloped surfaces will enhance runoff of unimpacted water from the BRSF, the HLF, and backfill. Net infiltration through these piles will also be limited by evapotranspiration from the soil cover, which

will also limit oxygen ingress. Unlike the BRSF and the HLF, which will have liners beneath the piles to prevent seepage of ARD to groundwater, the ARD from pit runoff will seep to and impact groundwater.

viii. *TOR Question: Can the waters flowing from acid drainage come into contact with surface and ground water systems? If so, how, in what period of time and with what consequences can this potential leakage contaminate surface and underground water systems, including those of Jermuk, Vorotan and Arpa rivers, adjacent tributaries and streams, Spandaryan and Kechut water reservoir hydro-technical structure, Lake Sevan, as well as change the chemical content of water and what consequences will occur as a result of this impact?*

Response: The answer to the previous question addresses impacts to groundwater by ARD. ARD-impacted groundwater becomes surface water at springs, streams, and rivers. Disturbed areas around the mine pits could generate ARD that runs off directly to surface waters. Ephemeral springs in the vicinity of the mine pits are the expression of short groundwater pathways. Seepage of ARD-impacted runoff from the pit walls can discharge within a timeframe of days to months, depending on the connectivity of fractures to the ground surface. Discharge from ephemeral springs during the spring snowmelt is evidence of the rapidity of flow through fractures on the mountain ridge. The time for ARD-impacted seepage to reach perennial springs and streams lower on the mountain sides is conceptually longer, but good connectivity for groundwater flow through faults and fractures could shorten the time commensurate with ephemeral springs at some discharge locations.

Ephemeral and perennial spring waters and groundwater emerging in streams high on the mountain sides can reach the major rivers in a few hours. For example, the Vorotan River is within 3 km of the mountain ridge. Assuming a moderate flow velocity of 0.3 m/sec, the transit time would be 2.8 hours.

The time for ARD-impacted groundwater to discharge at the major rivers is speculative and dependent on fracture connectivity. Data from pumping tests and tracer tests would be needed to estimate the time. Assuming the liner beneath the BRSF and the Toe Pond are effective in containing ARD seepage, impacted groundwater from the Project may not discharge to the Spandaryan-Kechut tunnel. Isotopic data do not support discharge of Amulsar Mountain ridge groundwater to the tunnel. Under the same assumption, the Kechut Reservoir and Lake Sevan would not be impacted.

Under conditions resulting from earthquake impairment of the BRSF, ARD-impacted groundwater could discharge at the northern end of the Spandaryan-Kechut tunnel, resulting in impacts to Kechut Reservoir and potentially Lake Sevan through the Kechut-Sevan tunnel. Likewise, impacted groundwater could discharge to springs and streams at the northern end of the Project area, in turn discharging to Kechut Reservoir. The transit time of this groundwater cannot be estimated with available data. Direct discharge of groundwater to the Kechut reservoir will not occur due to downward vertical hydraulic gradients beneath the reservoir. ARD-impacted groundwater will not reach Jermuk.

Earthquake damage to HLF, process ponds, BRSF liner, and contact water channels could release impacted water to groundwater and potentially directly to the stream in the vicinity of the HLF. A release to the stream would impact the Arpa River within a few hours.

The consequence of ARD releases to surface water and groundwater is loading of the rivers, reservoirs, and lakes with metals and other constituents that may result in exceedance of MAC standards. The extent of loading and change in concentrations is dependent on dilution and potential attenuation during transport. For example, precipitation of ferrihydrite and aluminum hydroxide could attenuate metals through sorption to these phases, as well as iron and aluminum. Statements about the potential extent of impacts to surface water bodies are conjectural without good transport and dilution analyses that are deficient in the ESIA. However, potential mixing of impacted waters, first with the Kechut Reservoir water and then Kechut Reservoir water with Lake Sevan water, would probably not generate significant or even measurable changes in concentrations of Lake Sevan water due to the sequential dilutions in both reservoirs and the size of Lake Sevan. This condition assumes whole lake mixing in Lake Sevan, not local concentrations at the discharge location of the Kechut-Sevan tunnel.

ix. *TOR Question: Has the extent of potential environmental damage, resulting from the exploitation of the mine, as well as the timeframe and cost of the mine's reclamation been properly calculated and subsequently justified in the EIA and the ESIA reports?*

Response: See the response to question xiii regarding environmental damage.

The total cost for Mine rehabilitation and closure and the duration of the post closure monitoring are underestimated as noted below:

- **The post closure operation, maintenance & monitoring (OM&M) period is limited to <u>only five years</u>. In the US, Federal and State regulatory requirements and guides for closure (e.g., RCRA 40 CFR Part 264.117; Nevada NAC 445A.446; USEPA, 2000) indicate post closure costs, especially when contamination sources remain, should be calculated for a revolving 30-year period (minimum). Post closure costs should include routine OM&M activities as well as periodic replacement, maintenance and repair actions that will be required after 5 years, which can be significant. The reduced post closure monitoring period and the omission of periodic replacement/repair costs will results in significantly underestimating the post closure costs.**

  Increasing the post closure monitoring period from 5 years in the ESIA to the conventional 30-year period, the total Mine rehabilitation and closure cost will increase from approximately $34M to approximately $70M (without adjustment for periodic replacement costs or realistic contingency) .

- **Contingency (scope and bid) is too low at 6% and underestimates the actual Mine rehabilitation and closure cost. The USEPA (2000) and AACE (2008a; 2008b; 2009) cost estimation guides indicate that at this level of project development (pre-feasibility) and the high degree of uncertainty (*e.g.*, unreliable data and PTS and need for additional studies, *etc.*) the contingency**

will likely exceed 20%. The Amulsar feasibility study (SGS, 2014 Table 21.5) used 16% for the initial capital phase.

Using a realistic contingency of 20% instead of the ESIA 6%, the total indirect cost percent would increase from 21.3% to 35.3%. Accordingly, the total Mine rehabilitation and closure cost will increase from approximately $34M (for the ESIA 6% contingency and 5-year post closure monitoring period) to approximately $78M (for 20% contingency and 30-year post closure monitoring period) without other adjustments.

- **Treatment requirements are likely unrealistic (actual costs are likely higher) due to incorrectly assumed low leachate concentrations and mass loading.**
- **Technical/professional costs (design/engineering, project management/ administration, and construction management) are underestimated at about 3% of total construction cost. USEPA (2000) indicates these costs are commonly greater than 15% for similar projects. The Amulsar feasibility study (SGS, 2014 Table 21.5) used 10% for the initial capital phase. Using 15% for these services would increase the total rehabilitation and closure cost by an additional amount on the order of $4M to $5M.**

x. *TOR Question: Taking into account the location of Amulsar mine, its geographical position, adjacent residential and health resort areas, can the exploitation of the mine with all of its processes of open pit mining, heap leaching and barren rock storage facility, be conclusively considered safe, and if not, what type of environmental damage can this result in?*

Response: The ESIA/EIA assessments are deficient and corresponding conclusions are unreliable. Accordingly, the question of whether exploitation of the ore deposit can conclusively be considered safe cannot be answered. The question about environmental damage is answered in responses to previous questions.

xi. *TOR Question: Do the processes of storing, transportation, use of toxic and dangerous materials, applied in production process, mentioned in ESIA and EIA reports, abide by regulatory requirements and international standards? Is there a proposed plan of action for prevention of leakage and emissions in case of natural disasters, and if so, is this plan scientifically justified and sufficient, or not?*

Response: *Processes of storing, transportation, use of toxic and dangerous materials, applied in production process, mentioned in ESIA and EIA reports, generally abide by regulatory requirements and international standards*.

The Emergency Preparedness and Spill Response Plan (Appendix 8.9 of the ESIA) includes preparing for and responding to overtopping/leak/failure of the solution and water treatment ponds, releases/spills of hazardous materials, and natural disasters such as earthquakes, flooding, and landslides. The document contains practical procedural information, not scientifically justified plans and actions.

River flood risk is extremely low. The contact water ponds have free-board to absorb increased runoff. The ponds were designed based on an updated SWWB that used stochastic analysis to account for a range of precipitation events, and the ponds were designed for a 100-year, 24-hour storm. According to the Nevada Division of Environmental Protection, ponds and diversion systems should be designed to have capacity for the 500-year, 24-hour storm event.

The mining infrastructure sites (buildings/foundations) that were designed based on a seismic hazards analysis are the HLF, BRSF, open pits, crushing plant, and overland conveyor system. See Section 2.1.1.3.2 for further details.

Noteworthy are the following statements in the Emergency Preparedness and Spill Response Plan with respect to each type of event:

- **Earthquake, Landslide, Subsidence, Erosion, or Other Geophysical Event:**

The Site has been designed to withstand any expected seismic events, and geotechnical testing conducted thoroughly. These measures should reduce the risks due to seismic events or landslip. No additional precautions are expected to be necessary as a result.

- **Overtopping of solution/storm event ponds:**

There is a low likelihood of such an event except in the most severe / unprecedented storm conditions. Given the volumes involved, it would be considered to be a Level III event.

- **Catastrophic Failure of HLF solution ponds:**

There is a low likelihood of such an event due to the design measures taken. In the event of such an occurrence, this would be treated as a Level III event

- **Cyanide Spill:**

All scenarios and potential incidents are to be treated as potential Level III and require specific response procedures as per the Cyanide Management Plan CMP) Ref GEOTEAM-ENV-PLN0221).

Level III is defined as follows:

A major incident beyond the resources of the Project, where there are subsidiary problems to complicate the situation such as fire, explosion, toxic compounds, and threat to life, property and the environment spillages. Assistance may be required from local, regional, and/or national organizations. The media will often be present and politicians at all levels will be requesting action.

xii. *TOR Question: Are the landslides in the surroundings of the Amulsar mining complex included in the ESIA and EIA reports and appendices? Do these reports include scientifically justified calculations and consequences of possible activation of landslides as a result of explosions? If not, what would be the potential and scientifically calculated chances and consequences of landslide activation as a result of explosions, and what* *type of geological damage and hydrological contamination, particularly to Jermuk mineral water basin, might occur?*

Response: Among the ESIA/EIA documents provided for review, there is no documentation of historic landslides surrounding the Amulsar Mine. Potential landslides are addressed in Section 2.4.4 of the EIA in the context of slope stability in the mine pits based on geotechnical data acquired through the exploration drilling program. The assessment is based on rock strength, RQD data, and orientation of discontinuities determined from rock core and includes the likelihood of earthquake-induced rock avalanches, slides, and slumps. The assessment does not pertain to the potential activation and consequences of landslides induced by blasting that would affect the environment and/or communities surrounding the Project. Landslides are mentioned in very few places in the ESIA and EIA. Section 6.8.2 of the ESIA addresses the unlikely risk of landslides contributing additional sediment load to surface waters in the context of soil destabilization due to removal of surface cover and high rainfall or snow melt. The Golder (2013) earthquake hazard assessment includes a Table 3.2 that describes landslide potential in terms of earthquake seismicity, but the report does not address the potential for landslides resulting from blasting. An assessment of potential landslide activation and the consequences is not possible with the available information.

xiii. TOR Question: Do the EIA and ESIA reports and appendices include a comprehensive assessment of the economic and financial damage caused to the human habitat, the air, land and water resources, as a result of the exploitation of the mine? Are these calculations scientifically justified and correct, if not, what is the financial and economic extent of this potential damage?

Response: Section 6 of the EIA addresses the environmental damage assessment. In this assessment, economic loss is calculated according to RA Government Decree 764-N dated May 27, 2015. Potential economic damage is calculated as a function of damage to soil resources, water resources, and the atmosphere. The scope of this 3rd Party Assessment does not include the assessment of natural resources or economic damages; noteworthy is that the assessment excludes a value for damage to water resources based on the assumption that no contamination will occur. On this basis, the assessment of potential damages is unrealistic.

4.2 Biodiversity

i. *TOR Question: Are the assessments presented by Lydian in the ESIA and EIA Reports and in the appendices attached to them sufficient, qualified, scientifically justified and comprehensive, or not; did the conclusions, derive from the reliable and actual data and was the methodology developed for these conclusions comprehensive and reliable?*

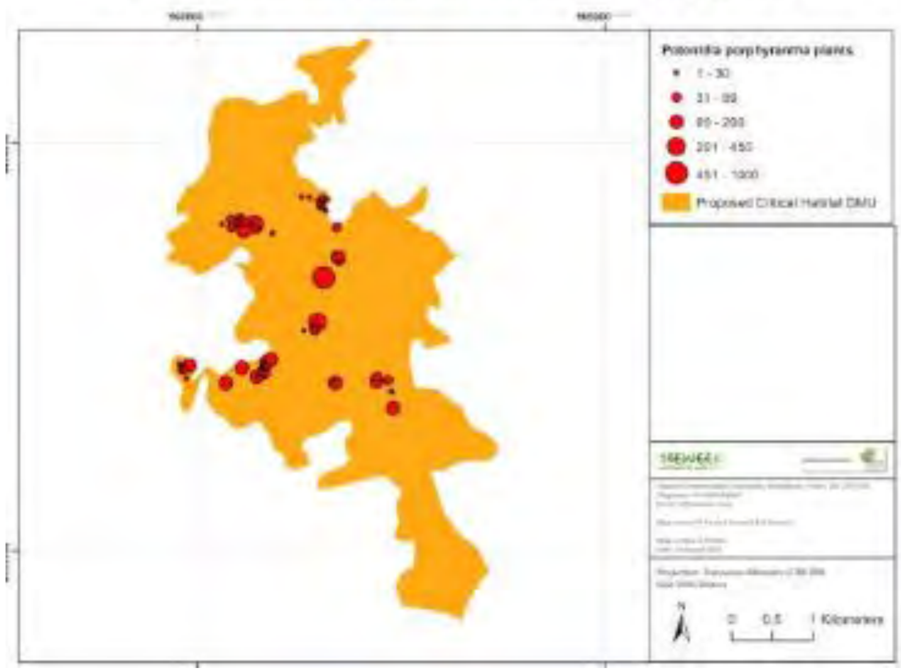
Response: The assessments presented in the report were performed by highly qualified scientists; they are generally to be considered suitable and therefore acceptable despite some data deficiencies and over simplification of the conclusions and interpretation of impacts.

Details on data deficiencies

1- The insect baseline assessment is mainly located outside project boundaries and therefore is necessarily lacking proper geographical coverage. In addition, functional ecological approach is missing.
2- The assessment for reptiles is under sized 7 days for 1800 ha and the habitat mapping for keys species is missing.
3- Bird assessment is missing the night surveys for *Bubo bubo* and no functional habitat description for priority species.
4- Summer surveys for bats are missing to enable proper evaluation of bat activity and no functional map (hunting areas, transit areas and shelter areas) is included.
5- A clear overestimation and mis-illustration of habitat of *Potentilla porphyrantha* leading to an underestimation of the impact of the project.

The distribution map of *Potentilla porphyrantha* (sampled points) is provided without description or mapping of the critical habitats for this species identified as “subalpine meadow with alpine elements” (in green in the below map) in which the species occurs on suitable rock substrate (see photo).

Figure 4.10.6: Small boulder with 50 plants of *P.porphyrantha*

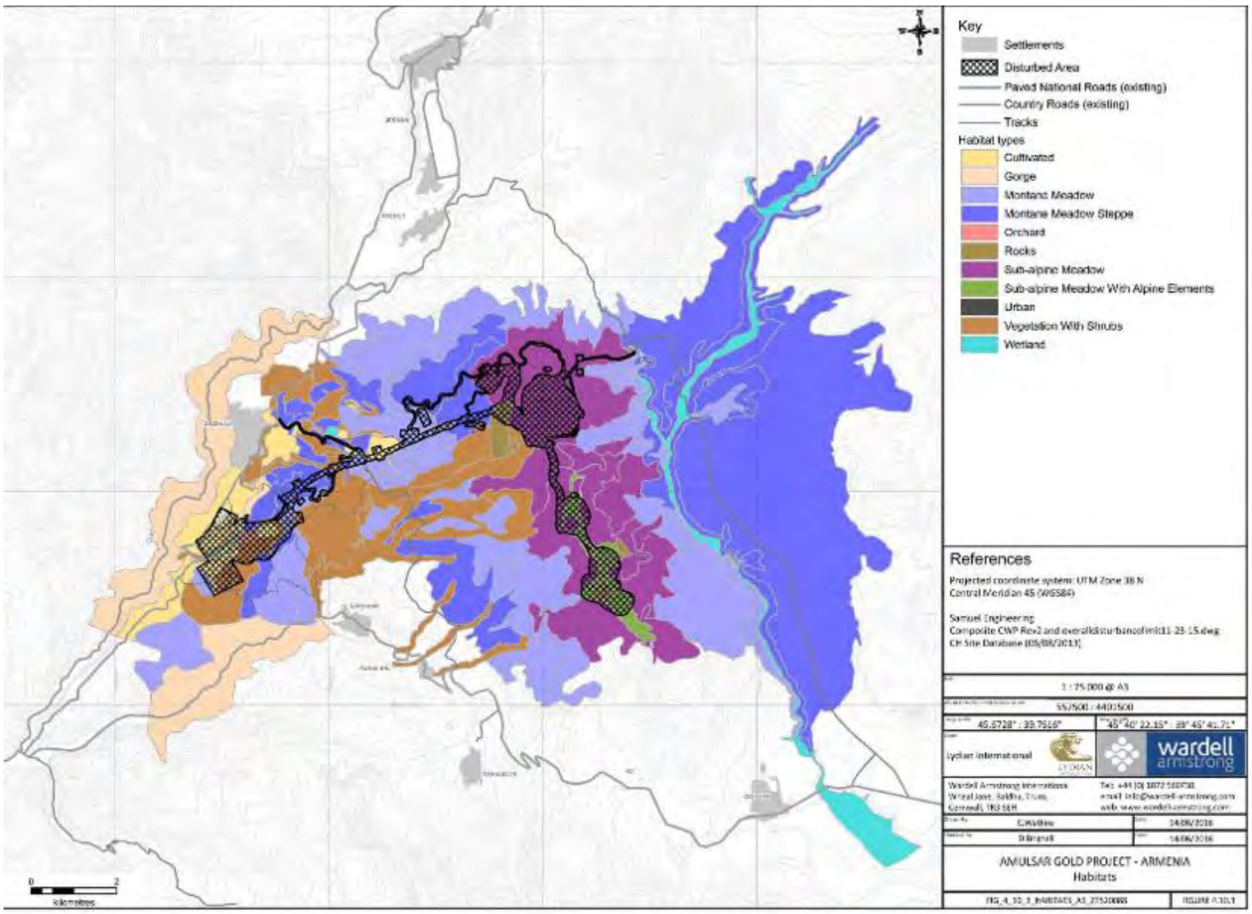


As per the map, the habitat will be heavily impacted by the project. The report states

"The physical footprint of the project on this species is estimated to be on 150.5 hectares (12.5% of the total area of critical habitat)".

This assumes that the species occupies the entire area of critical habitat (1200 hectares) when it occurs only on a subset of the area where suitable habitat occurs. Therefore, 12.5% is an underestimate of the area occupied by this species.

Effort to count of all individuals; a precise map of species habitat would have significantly improved the estimate of project physical footprint and potential mitigation.



ii. *TOR Question: Does the monitoring program presented in Lydian's ESIA and EIA, include all necessary components (habitats, flora, fauna) of the environment?*

Response: The document presents a clear monitoring program for habitats and key species of high ecological concern for flora and fauna.

The mitigation measures suggested for *Potentilla porphyrantha* are still experimental and should therefore be considered as ongoing accompanying measures instead of mitigation measures. In this configuration, an offset program on *P. porphyrantha* is recommended especially in view of the time laps needed to reach conclusive results in the experiments.

Extracts from the report

« Confirmation of the need for an offset is contingent on a) monitoring results showing more extensive impacts than predicted, with decline in the condition and/or survival of plants in the residual population on Amulsar Mountain; b) research through the BAP failing to improve understanding of the species' ecology and requirements; c) failure to propagate or grow the species successfully ex-situ from seed; d) lack of confidence that suitable conditions can be created post-mining; or e) results of genetic studies suggesting the Amulsar population is genetically distinct or unique".

To our evaluation the need for an offset is required whenever no conclusive demonstration on the absence of residual impact is reached.

iii. *TOR Question: Are the arrangements, foreseen by the program sufficient in terms of the set standards, or not?*

Response: The report has abided by the Republic of Armenia's legal framework as well as lenders' standards and International Conventions.

However, as presented, the mitigation and offset measures do not enable to convincingly reach the No Net Loss and Net Gain on biodiversity as claimed, and some major impacts have been underestimated to lead to proper mitigation measures and subsequent estimation of residual impacts.

Extracts from the report:

« Although the process of identifying specific offset interventions is not fully complete, the majority of these species is expected to benefit from the Project's natural habitat offset, through "additional conservation actions". These would form part of the Project's adaptive management approach, with further specific offset interventions being identified and implemented for these species and for migratory raptor species of conservation importance, if monitoring showed decline in breeding or feeding activity due to unforeseen Project impacts"

To our understanding, the offset program cannot be in development phase when the ESIA has been finalized. It should not include such broad statements as “majority of the species” and “additional conservation actions”.

iv. *Taking into account the location of Amulsar mine, its geographical position, were the impact of activities on biodiversity (ecosystems, habitats and wild species) properly assessed and considered?*

Response Major ecological stakes and major receptors were adequately identified in the report.

Improving baseline assessment by adopting functional ecological approach could improve the conclusions.

v. *TOR Question: Do the EIA and ESIA reports and appendices, as well as the plan for mine closure include comprehensive and scientifically justified measures for the preservation or restoration of the fertile topsoil?*

Response: The measures reported are mainly experimental trials for the preservation and future restoration of the top soil. No conclusive results on suggested future restoration measures are presented, enabling a clear answer to this question.

vi. *Is the conservation status of patrimonial species (endemic, vulnerable, rare) including Potentilla porphyrantha and Acantholimon caryophllaceum and Parnassius appolo among others properly assessed?*

Response: The conservation status of *Potentilla porphyrantha*, *Acantholimon caryophllaceum* and *Ursus arctos* were properly assessed.

Other species of importance are lightly addressed throughout the various sections of the report.

Details

Some key species (receptors) are missing appropriate mitigation measures and therefore offset program, especially the lesser Kerstrel, the Eastern rock nuthatch and the ursini viper group.

No exhaustive baseline for insects is provided.

vii. Is the Biodiversity offset program proposed, effective and applicable?

As presented, the BOP can only be partially implemented since suggested actions are not geolocated, nor are they presented in a detailed operational method. The major contribution of the BOP is to finance the Jermuk National Park over 5 years;

4.3 Air Quality

i. Are the assessments presented by Lydian in the ESIA and EIA Reports and in the appendices attached to them sufficient, qualified, scientifically justified and comprehensive, or not; did the conclusions, derive from the reliable and actual data and was the methodology developed for this conclusion comprehensive and reliable?

Response: Most tools used in the assessment are suitable and are consistent with acceptable and standard practices. However, some of the key elements were not assessed in the baseline and their impact was not assessed with a sound methodology. The Raduga model used for the assessment of the boilers and the ADR plant is not appropriate taking into account the site of the project. However, emissions of TSP and PM_{10} from fugitive emissions along with their impact assessment were reliable. Further limitations identified are presented in the response to Question ii.

ii. Were the resultant emissions from the controlled immovable sources calculated correctly, or not; are these scientifically justified and correspond to the regulatory requirements, or not? If they are not, the assessment is to provide what would be the resultant emissions from the controlled immovable sources and what would be the extent of harmful impact on the air, water, biodiversity, land and health of the population?

Response: The immovable sources consist of boilers and the Gold ore processing plant. Boilers emissions were assessed properly. However, their impact was assessed using the Raduga model which is considered not appropriate for this exercise. The impact of the boilers is not expected to be significant but a proper modeling shall demonstrate it. As for the ADR plant, emissions were not estimated correctly: the assessment did not consider Hg and did not present a solid estimation of the emissions for HCN and HCl. These emissions shall be determined by the process and plant manufacturer since these are much dependent on many variables in the process configuration. Afterwards, a proper modeling shall be conducted as for the boilers taking into account the baseline for these pollutants at the receptors' locations in order to set the emission limit values since these do not exist on the national level. Electrical generators are mentioned in the SOP for Air Quality Management and monitoring for the construction phase but these sources are not mentioned in any assessment and it is not clear whether they will be used in the operation phase or not. Abatement techniques for HCN and HCl are well-known and controlled with the alkaline solutions. Emissions following effective control equipment are not expected to be high. Settlements are located relatively far from the plant and emissions are not expected to breach the ambient air quality standards. Mercury emissions are not expected to be high since the content of the soil as indicated in the ESIA is already at most of 0.05 g/t and with the different emissions abatement, air quality

standards are not expected to be breached. The most toxic of these compounds is mercury. WHO states that exposure to mercury – even small amounts – may cause serious health problems, and is a threat to the development of the child in utero and early in life. It may have toxic effects on the nervous, digestive and immune systems, and on lungs, kidneys, skin and eyes. WHO considers Hg as one of the top ten chemicals or groups of chemicals of major public health concern.

iii. *Does the monitoring program, presented in Lydian's ESIA and EIA, include all necessary components (land, air, water, flora, fauna, etc.) of the environment and are the arrangements, foreseen by the program, sufficient in terms of the set standards, or not?*

Response: The environmental monitoring program related to air quality is acceptable but is suggested to be augmented to better monitor and control the sources of pollution and their impacts. These additions mainly relate to the monitoring of stationary sources.

iv. *Are the calculations of the range of dust expansion, as the result of exploitation of the mine complex, as well as the proposed measures for lessening and preventing their harmful impact as suggested in the EIA and ESIA reports scientifically justified?*

Response: Emissions of fugitive dust from the mining activities, namely TSP and PM_{10}, were generally calculated correctly and their impact is negligible on the settlements (from around 1 km and beyond) in line with available international guidance. $PM_{2.5}$ emissions were not estimated and their impact on the settlements was not assessed properly, proper modeling shall be conducted with a proper model that takes into account the complex wind field in the area. The impact is expected to be low on the receptors but needs to be assessed. The mitigation measures are suitable for the project and acceptable. Additional measures were suggested to lower further the impact of dust expansion.

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Appendix A: Amulsar Block Physiographic Map and Geologic Map of Vayots and Faults Alignments

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About the mine

Amulsar gold-bearing quartzite deposit (the Project) is located on the borderline of RA Vayots Dzor and Syunik Regions, within the ridge area of north, north-western branching of Zangezur Range, at the elevation of 2500-2988m.

Reserves of Amulsar gold-bearing quartzite deposit were explored, estimated and given a commercial value as a result of large-scale geological exploration activities at Mountain Amulsar undertaken by Lydian Armenia.

Structurally, the Project is located on the north-eastern edge of the Zangezur ore zone and hosted by two large ore-bearing and non-metallic sequences.

1. Ore-bearing, upper volcanic sequence comprises andesitic volcaniclastic rocks, breccias and tuff (“andesitic coat”), which strikes meridionally about 5,000m, and the thickness is up to 350-400m.

2. Non-metallic, lower volcanic sequence comprises argillically altered homogeneous and non-clastic andesitic rocks. The sequence thickness ranges 100-300m (Middle Eocene).

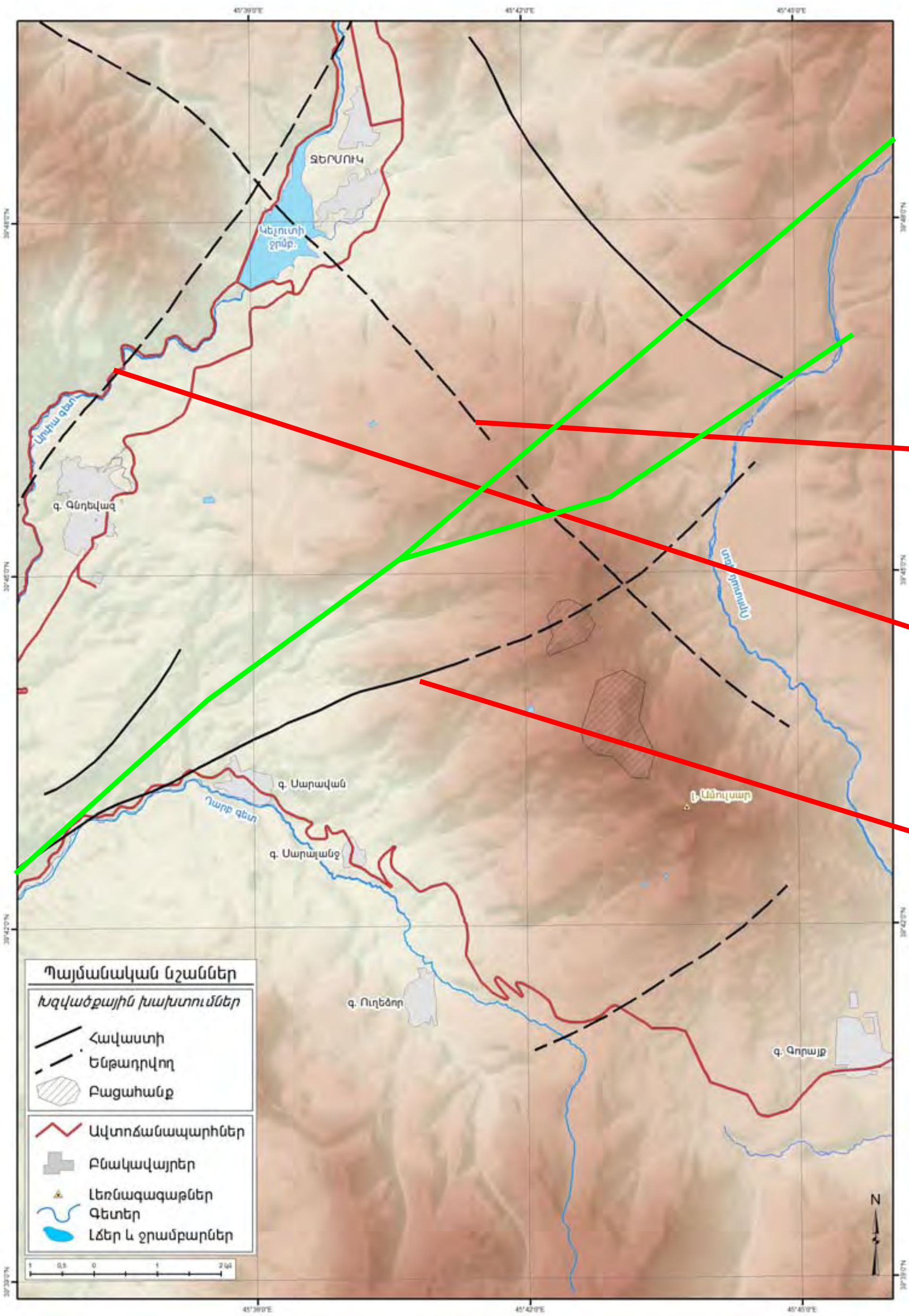
From all the sides the Amulsar tectonic block is confined to major faults, out of which Kechut-Zirak cross fault striking along the northern boundary is noteworthy. From the village of Kechut this fault stretches over the Volcano Zirak to the Vorotan riverheads and it is characterized by the outcrops of minor intrusions and hydrothermally altered rocks, and the mineralization is localized in its upthrown side.

The Amulsar deposit has independent hydrogeological conditions favorable for the mine operation, mining and drilling activities. Hydrogeology of the deposit is distinguished with its independent conditions and in no way it has any connection to mineral and freshwater basins, springs, especially to Jermuk mineral water deposit, which is fed from another tectonic block. From Amulsar it is straddled by deep major Kechut-Zirak fault, located in low 1,000m hypsometric area and is fed from deep layers.

Exploration activities in the Amulsar ore zone identified combined Tigran-Artavazdes, Erato, Arshak and Orontes sites with their own internal structures.

Reserves of Tigranes-Artavazdes, Erato sites have been approved in accordance with RA legislation, and the right for their operation belongs to Lydian Armenia. Lydian Armenia owns all the approved reserves of the deposit, amounting to 89,376.3 Kt of ore; 73,733 kg of gold (average grade of 0.78 g/t) and 294,367 t of silver (average grade of 9,29 g/t).

The deposit is to be developed by combined Tigranes-Artavazdes and Erato open pits, with the annual mining output capacity of 10 Mt of ore.



Metals from the deposit are to be extracted by heap leaching method, which is common international, and will be used in Armenia for the first time.

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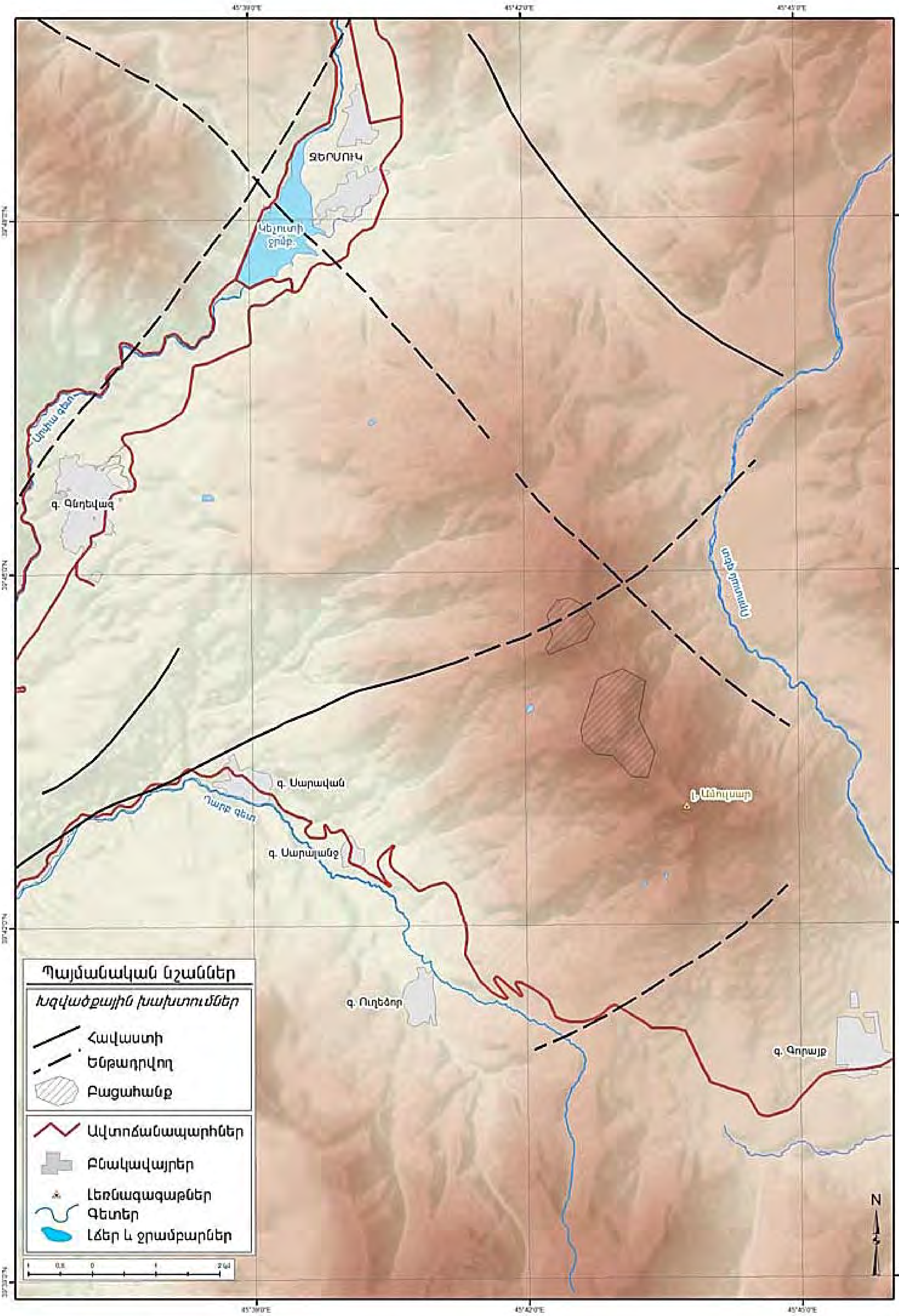
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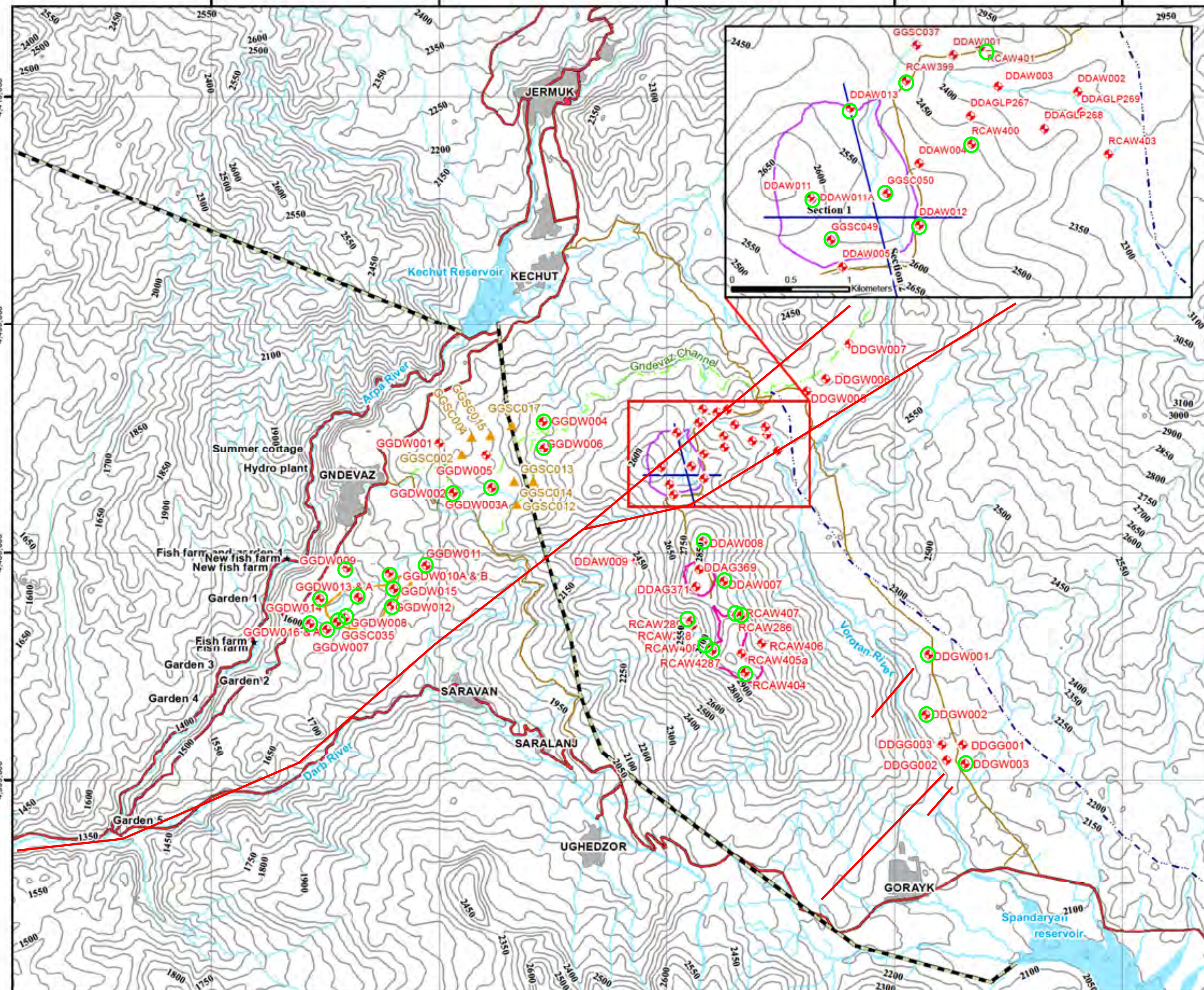

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Legend

Groundwater Level Monitoring Locations

- Groundwater Well
- Open Borehole
- Landmark
- Lines of Section, Drawings 4.8.5 and 4.8.6
- Road
- Gas Pipeline
- Tunnel Arpa Sevan
- Contour (10 metre)

Mine Facilities

- Mine Pit
- Barren Rock Storage Facility
- Heap Leach Facility
- Watercourse
- Town

REFERENCES

Coordinate System: WGS 1984 UTM Zone 38N.
Data provided by client

0 1.5 3 6 Kilometers

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PROJECT

AMULSAR GOLD PROJECT ESIA

TITLE

CURRENT AND HISTORICAL GROUNDWATER LEVEL MONITORING LOCATIONS

Golder Associates
Bourne End, UK

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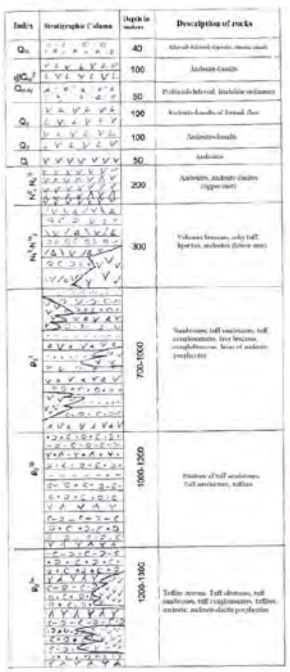
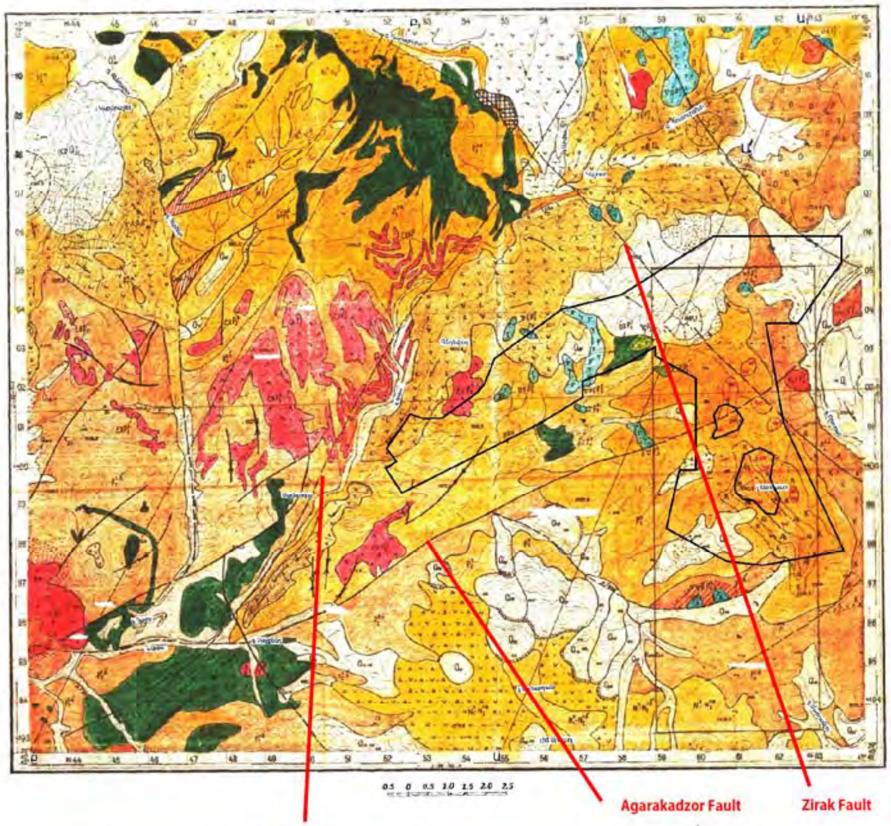
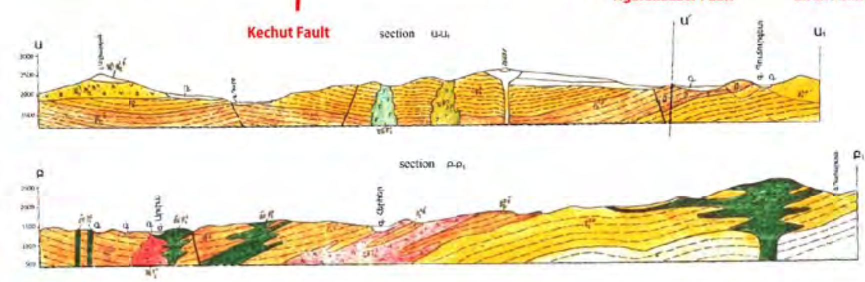
GEOLOGICAL MAP OF VAYOTS DZOR, ARMENIA

Scale 1: 50 000

STRATIGRAPHIC COLUMN







LEGENDS

Quaternary
- Recent alluvial and lacustrine sands, pebbles, clay sands, clay, loam and other
- Recent (early) lavas: Andesites, andesite-basalts, volcanic sands of volcano Vayots Dzor
- Upper Quaternary-Recent sediments. Proluvial-deluvial gravel, screes, pebbles, clay sands
- Middle-quaternary andesite-basalts
- Lower-quaternary andesites

Neogene
- Upper Miocene-Lower Pliocene. Upper sequence. Andesites, andesite-dacites
- Upper Miocene-Lower Pliocene. Lower sequence. Volcanic breccias, ashy tuff, liparites, andesites

Paleogene
- Upper Eocene-Oligocene. Sandstones. Tuff sandstones, tuff conglomerates, lava breccias, conglomerates, lavas of andesite porphyrites
- Tuff sandstone stratum. Tuff sandstones, tuff siltstones, tuffites
- Tuffite stratum. Tuff siltstones, tuff sandstones, tuff conglomerates, tuffites. In some places with Interstratal and interformation bodies of andesite, andesite-dacites.

SUBVOLCANIC ROCKS

- Upper Eocene dacite porphyries (ζπ)
- Middle-Eocene dioritic porphyrites (δπ)

INTRUSIVE ROCKS

- Late Oligocene quartz syenites, granosyenites (γξ)Granodiorites, granosyenites, diorites, monzonites without dissection (γξδ), gabbro, gabbrodiorites (νδ), olivinic gabbro, monzonites, anorthosites without dissection (νπξ), anorthosites (ν)
- Diorite-porphyrites (a), gabbro porphyrites (b), dacite porphyrites (c) andesites (d), basalts (e)
- Granites (a), syenites (b), diorites (c), gabbro (d), olivinic gabbro (e), anorthosites (f)
- Clay, sands
- Volcanic sands
- Calcareous tuff (travertine)
- Contact hornstones
- Hydrothermally altered, limonitized, kaolinitized, ochred, pyritized rocks
- W A K O — Formation of secondary quartzites (Amulsar ridge and other). Monoquartzites ( ), alunite quartzites ( ), kaolinite quartzites ( ), silicification ( ).
- Borders: (a)between formations of different ages, (b) lithological and facial subdivisions of the same age
- Cinder cones (hornito) – volcanic centers with crater
- Falling-landslide formations
- Main dislocations with break of continuity: a) certain, b) inferred, в) identified by aerial surveys
- Faults without considerable displacement
- Place of findings of fossil organic remains (exuviaes)
- Attitude of beds inclined
- Direction of lava flows

REPUBLIC OF ARMENIA

GEOTEAM

CLOSED JOINT STOCK COMPANY

WORKING DESIGN

Company: **GEOTEAM CJSC**

Project: **Amulsar gold-bearing quartzite deposit, RA Vayots Dzor Region**

Sections: **Geology**

GEOTEAM CJSC

General Manager **Hayk Aloyan**

Yerevan – 2014

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T A B L E   O F   C O N T E N T S

1. GEOLOGY

1.1. Geographical and economic description of the area

Amulsar gold-bearing quartzite deposit is on the borderline of Armenia's Vayots Dzor and Syunik Regions, in the ridge part of north-northwest branching of the Zangezour Range, at the altitude of 2500-2988 m. The mineralization area is located 12 km NW from Gorayk village of Syunik Region, and 10 km south from Kechut village of Vayots Dzor Region. The villages Saravan and Ughedzor are the adjacent settlements.

The Amulsar Mountain of the Zangezour Range is the dividing line between the Rivers Arpa and Vorotan, maximum elevation of which is 2,987.8 m (Amulsar).

In the recent erosion cross section, the Mount Amulsar rises up as a meridional major four-headed oval-ellipsoidal cone step-like cut morphological structure, the peaks of which relatively differ from each other by approximately 20-25 m, maximum up to 110 m. The area of the cone base with the radius of 2 km, edging with the outcrops of unaltered rocks and secondary quartzites, is 12 km^2. The ridge-top part with oblique section and 1 km radius has an area of 3.5 km^2.

The area is woodless. The vegetation cover is represented by shrubs and alpine meadows.

The main rivers are Arpa and Vorotan with their numerous streams. The River Darb, tributary of the River Arpa, flows through the license area.

Three climatic zones have been identified, such as lowlands with dry continental climate, and plateaus with steppe climate for the highlands, and the alpine climate predominates in the ridges. The average yearly amount of rainfalls in the lowlands of the area reaches 300 mm, on the foothills – 400-500 mm, and in the ridges – 500 mm. 20-30 cm topsoil freezes in winter. The snow remains here for about 6 months. The prevailing winds direction is north-eastwards. The eastern winds are dry, and the western ones are wet.

The area has a well-occurring infrastructure. Iran-Armenia gas pipeline and high-voltage power transmission lines pass south the Project area. It is planned to lay a railway line and a trunk highway to Kapan and Meghri (North-South Project) along the ravine south the Project area.

Ore and nonmetallic mineral resources have been prospected and explored in the region. Azatek gold-polymetal and Kaqavasar polymetal deposits are the projects prospected in more details.

The area is rich in building materials, out of which andesitic basalts, volcanic tuffs and slags, limestones, sands and other sand detrital formations used in local construction have widespread occurrence in the area.

The population is mainly engaged in farming. Animal husbandry is well-developed.

It will be possible to provide the proposed mining enterprise with work force through hiring people from the villages Saravan, Gndevaz, Gorayk, Kechut, etc.

1.2. Geological structure of Amulsar deposit

Structurally, Amulsar deposit is located on the north-eastern edge of Zangezour ore megazone, which is the boundary of Armenian-Iranian post-Baykal plate, where Mesozoic and Caenozoic tectonic-magmatic formations occur intensively.

The structure of the Amulsar deposit is comprised of two major sequences (from up to down)

1. Ore bearing, upper volcano-sedimentary sequence consisted of andesitic volcanic debris, breccias and tuff (andesitic “cloak”), which are strongly broken in the oxidation and hypergenesis zone, washed and represented by various sedimentary formations: kaolinisation, silification, alunitization, migmatization. The thickness of the sequence reaches up to350-400m. It is of Upper Eocene-Lower Oligocene age. It is overlaying various layers of Eocene.

2. Non-metallic, lower volcanoclastic sequence, consisted of argillitized andesitic rocks, which are homogenous and not broken. The thickness of the sequence is 100-300m. It is of Middle Eocene age.

The andesitic “cloak” of Amulsar deposit stretches meridionally about 5,000m, and the rocks are fractured along its boundaries, mostly in the extrusions of andesitic breccias and brecciated volcanic rocks, which has created favorable conditions for vein and disseminated, i.e. gold-bearing stockwork mineralization and further recent infiltration processes.

Basically the Amulsar deposit borders with the above sequences and is comprised of discrete mineralization centers, which occurrence regularity is due to major ore control structure. Tigranes-Artavazdes, Erato, Arshak and Orontes sites are identified with their particular internal structures.

The ore control structure is represented by:

1. Amulsar ore control north-northwest striking faulting zone dipping south-westwards, and the mineralization is localized in its hanging wing. This is the first category fault.
2. Tigranes-Artavazdes joint ore zone, striking north-eastwards and bordering with Tigranes and Orontes faults. This joint ore zone has occurred in the center of northeastern (Tigranes Site) and southeastern (Artavazdes Site) fracturing. Tigranes-Artavazdes zone is younger, than the

Amulsar ore control zone. The thickness of the ore zone is 600-1200 m. From the south the ore zone is confined to the northwest striking Arshak fault. The faults of Tigranes-Artavazdes ore zone are second category faults.

3. Tigranes-Artavazdes ore zone in the central part of the Site Tigranes crosses with the northwest striking Southern Erato fault, and from the north-east the mineralization borders with the Northern Erato fault. The internal structure of the Erato site is due to the center of northwestern and southeastern faults. Northwestern faults of Amulsar deposit area are third category faults, and all intrastructure faults (fractures) – fourth category.

The mineralization of the Amulsar deposit is mostly localized in altered and silicified breccias, which have been subject to oxidation and hypergene alterations. On the surface the Tigranes-Artavazdes ore zone has isometric-oval contour with the length of 800-1,500 m, and the width – 600-800 m. The ore body is traced by drill-holes to 120-250 m depth. Deeper parts are observed in the near root of the extrusion of breccias, where the inclination of the ore body (angle of dip) changes from horizontal to 20-25^0. The lower limit of mineralization is undulating, caused by the contact of the altered and silicified breccias and underlying solid andesit and the boundary of oxidation zone. In fact, currently contoured commercial ore body is located within the boundaries of the strongly oxidized breccias.

Geotechnical surveys proved the high grades of gold to be accompanied by slight mineralization of silver with the grade of 1-4 g/t, which is typical to similar structures and is considered one of the hypogene features. This ore contains no lead, zinc and other metals.

Site Erato is located to north-west (500-750 m) from Tigranes-Artavazdes, where detailed prospecting and exploration activities were undertaken. Geoteam has carried out large-scale core and RC drilling with depth of up to 404m, sampling of surface volcanoclastic rocks, mechanical trench sampling of rocks, geochemical and geophysical complex surveys (magnetic survey, induced polarization, electric prospecting) and hydrogeological activities.

Erato Site is at the elevation of 2,900 m. The oxidation processes occur intensively, and they have traced to 404 m depth by drill-holes. The intensively altered rocks, such as iron oxides and hydroxides, copper secondary sulfides are striking deeper horizons as compared with Tigranes-Artavazdes site.

The oxidation and alteration of rocks, as well as lenticular-dissemination occurrence of leached metals prove the concentration of metals in deep horizons, this means a secondary mineralization zone has been identified with typical chalcosine, covelline and bornite. In this site gold mineralization also occurs in the secondary quartzes rich in iron oxides and hydroxides. These quartzites have been generated in andesitic brecciated inclusions, mostly localizing in intensively fractured bodies forming vein and disseminated concentrations. Here the limonitization and ochring occur relatively slightly.

In Erato Site the ore zone has a rounded morphology (650x650 m) and is traced at about 350 m depth. The ore zone is controlled by Northern and Southern Erato faults, which strike in near-latitudinal (northeastern) direction.

Two large sites have been explored in the area of Amulsar deposit so far. They are discrete centers of mineralization of the combined structure. This combined mineralization centers probably merge at the depth creating a whole porphyric complex, the upper stage is represented by gold-silver mineralization of secondary quartzites.

The hydrogeology of the Amulsar deposit is favorable for further development, exploration, mining and drilling activities. The geological structure of the Project area, as well as the morphology of Amulsar deposit located 800-1000m upstream the catchment basins of the rivers Arpa and Vorotan, ensures hydrogeological independent (autonomic) conditions. There is no common water-bearing layer in the Project area. Water chemistry is hydrocarbonate-chlorite-calcium and hydrocarbonate-calcium. The hydrogeology of Amulsar deposit has an independent regime and by no means they have any relation to mineral and freshwater springs of adjacent areas, particularly with Jermuk mineral waters, which are feed from other tectonic block, bordering with Kechut major deep fault and located at hypsometric low level and fed from deep layers.

Amulsar deposit has been formed at shallow depth, at low temperature environment. Gold is represented in finely dispersed form. The mineralization is controlled by faults and concentrates in altered silicified brecciated formations.

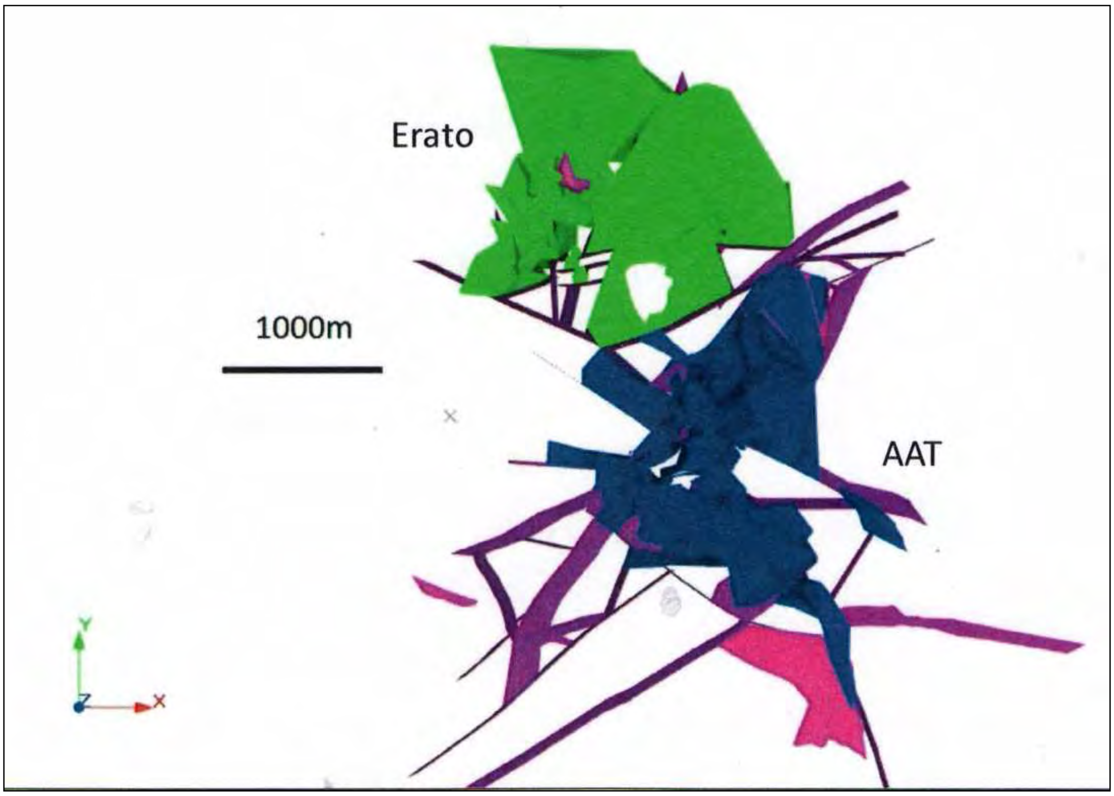


Fig. 1. Location of Amulsar Project Sites by fault tectonics

All the features of high-sulphide epithermal-infiltration gold-bearing system occur in the Amulsar Project area. Thick volcanic dome consists of the pre-ore sequences of lower volcanoclastic rocks and upper andesitic tuffs and ignimbrites. These sequences are gently dipping north-eastwards and they are broken by andesitic brecciated multi-stage extrusions. The latter have occurred in two stages, which caused to occurrence of two phases of hydrothermal alterations. The solid quartzites (monoquartzites), which are the outcome of pre-ore alterations, supported localization of the low-grade disseminated gold mineralization. The second-phase quartz-alunitic alterations occurring later were more favorable in terms of gold-bearing, especially in clastic rocks associated with dome-like extrusions and hydrothermally altered breccias. Gold was separated and localized primarily at the second phase, with brecciated extrusions and their adjacent structures.

Almost everywhere in higher parts, rocks are altered up to homogenous quartzites (pre-ore “monoquartzites”), and in lower parts spotted quartzite to quartz-alunitic and clay facies are observed.

It should be noted that the oxidation zone (up to 100-150m deep and more) occur in Amulsar deposit, which is proved by the wide-spread occurrence of iron hydroxides and commercial grades of mineralization at these depths, as well as the infiltration mechanism of formation, which is the result of the occurrence of gold on secondary limonite.

The base of Amulsar volcanic system consists of underlying sequences of volcanoclastic and brecciated flows. The dome flow complex is broken by andesitic second-phase brecciated extrusions, where the mineralization is distributed.

In the central part of the deposit the alteration of rocks is so much intensive that it is not possible to determine the primary structure and mineral composition of igneous rocks. In the parts where the alterations are slight, one can see a homogenous structure of andesitic rocks, where plagioclase fine prevail. Also smaller augite impregnations and fine grains of feldspar are observed.

Hydrothermal (secondary) breccias: Their components have been cemented under the influence of hydrothermal solutions. The hydrothermal breccias occurred at the late stage of gold mineralization. The clastic material consists of both homogenous and heterogeneous separations. Breccias often have not typical fracturing. Sometimes the fragments are ground, in other cases they are not ground and they are broken.

Dykes: Dykes have various composition, a part of which is related to dome extrusions, and some parts are not classified. The edges of calcination are apparent in the contact of dykes, which can be seen from the layering of altered rocks and residues of volcanic structures. Barite dykes are encountered as well. Sometimes they are represented by mass barite covered by the film of coarse-crystalline limonite. Sometimes barite contains powdery formation partly represented by yellowish antimony hydroxide (stibiconite), which has occurred due to the antimonite crystallines.

The other part of powdery formations is represented by bismuthite (bismuth carbonate oxide). The barite dyke also accompanies the ore body of Artavazdes Site. Some increase in the gold grade is seen in barite dykes.

The shallow faults in the sites of the Project are well-defined and their occurrence is based on the formation of clay material in the contacts of altering rocks. Dykes and hydrothermal breccias often concur with faults. Some of them are argillitized, the others contain abundant granular quartz.

Volcanoclastic and volcano-breccia formations are well-defined in the deposit. They are broken by Lower Oligocene (Upper Eocene-Lower Oligocene) intrusive rocks.

The Amulsar Project area has a block structure and from the north it borders with Zirak deep fault, which is clearly seen on the surface with outcrops of gabbroidic, granite-syenitic and granitoidic minor intrusive rocks, along the northern flank of the synclinorium.

Three intrusive formations are identified in the Zirak faulting zone: gabbroids, syenites and granite-diorites.

1. The outcrops of *Jermuk* intrusions are exposed in the area between the town of Jermuk, Kechut village and the ruins of the village Zirak.
2. Separate outcrops of *Kechut* intrusions are exposed NE Kechut village, from under the Quaternary lava covers.
3. *Upper Vorotan* intrusions outcrop upstream Vorotan River, spread on two banks of the river,

The Eocene volcanic and volcanoclastic rocks of Amulsar Project area are divided into three groups:

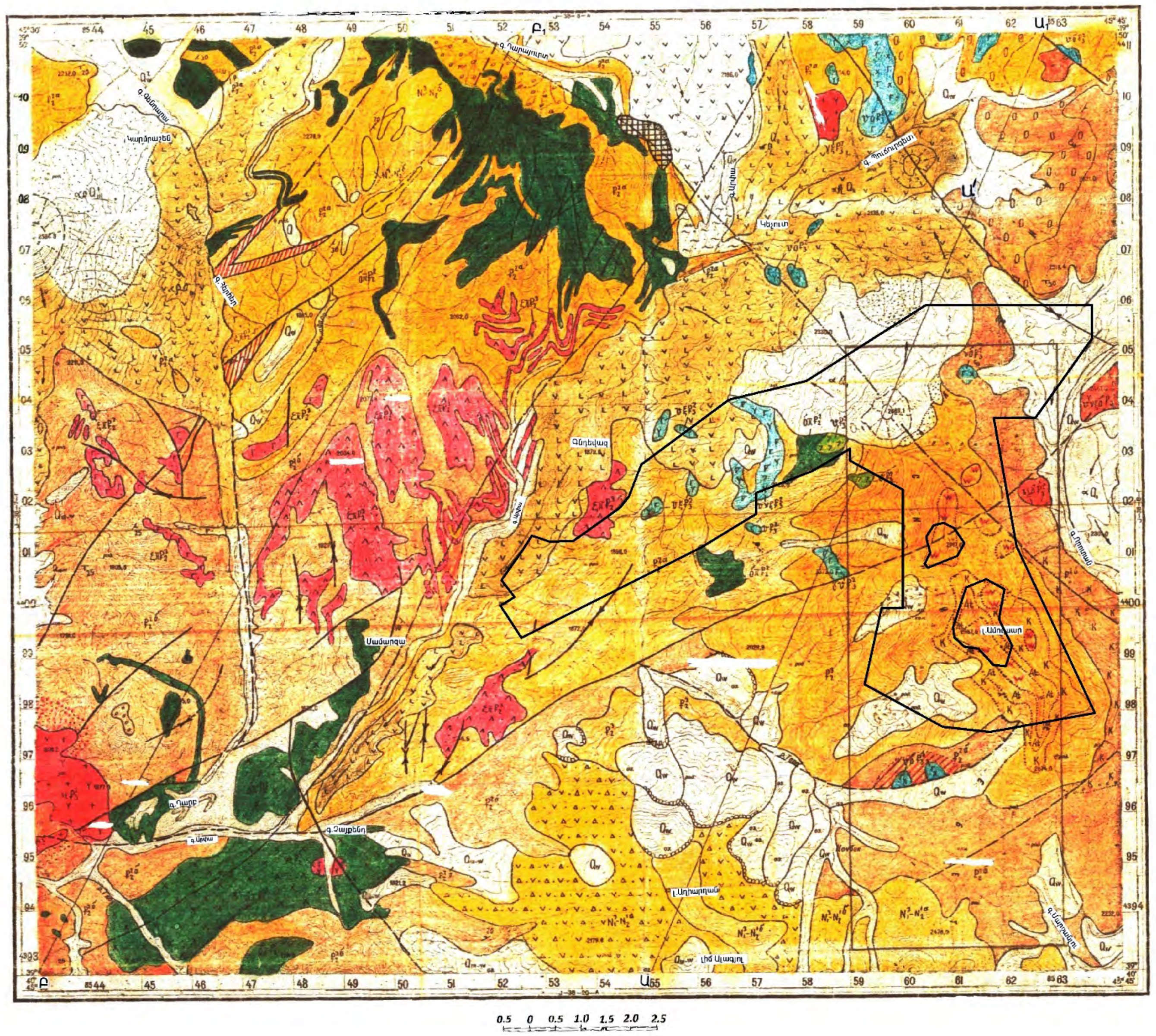
1. Gold-mineralized secondary quartzites altered by iron oxides and hydroxides. They are represented by variety of hematite, geotite, magnetite, limonite, also their intermediate varieties.
2. Primary non-mineralized andesites and plagioandesites and sericitic, rutile-alunitic secondary quartzites.
3. Monoquartzites, rutile and rutile-alunitic secondary quartzites with fine-grained sulphide and overlying superegene ferric mineralization.

GEOLOGICAL MAP OF VAYOTS DZOR, ARMENIA

Scale **1: 50 000**

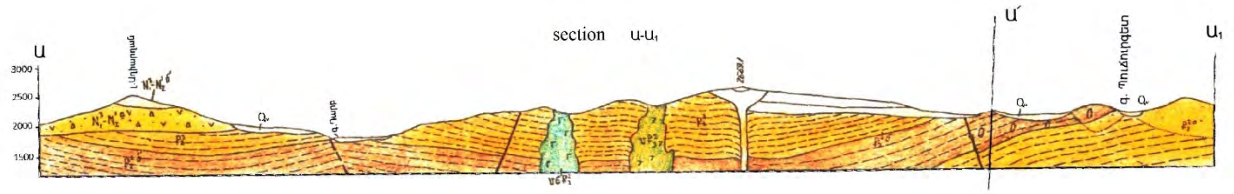
STRATIGRAPHIC COLUMN

Index	Stratigraphic Column	Depth in meters	Description of rocks
Q_{IV}		40	Alluvial-deluvial deposits, stream canals
$x\beta Q_{IV}^2$		100	Andesite-basalts
Q_{III-IV}		50	Proluvial-deluvial, landslide sediments
Q_{II}		100	Andesite-basalts of Jermuk flow
Q_{II}		100	Andesites-basalts
Q_I		50	Andesites
N_1^3-$N_2^{1б}$		200	Andesites, andesite-dacites (upper unit)
N_1^3-$N_2^{1\alpha}$		300	Volcanic breccias, ashy tuff, liparites, andesites (lower unit)
₽$_2^3$		700-1000	Sandstones, tuff sandstones, tuff conglomerates, lava breccias, conglobreccias, lavas of andesite porphyrites
₽$_2^{2\beta}$		1000-1200	Stratum of tuff sandstones. Tuff sandstones, tuffites
₽$_2^{2\alpha}$		1200-1300	Tuffite stratum. Tuff siltstones, tuff sandstones, tuff conglomerates, tuffites, andesite, andesite-dacite porphyrites

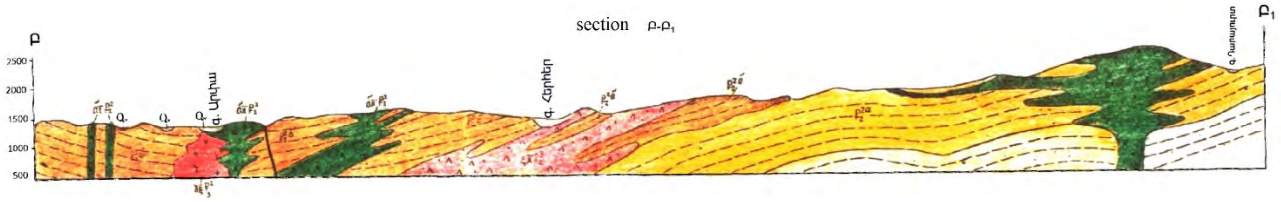


0.5 0 0.5 1.0 1.5 2.0 2.5

section U-U$_1$



section P-P$_1$



LEGENDS

Quaternary

- Q_{IV}^2 — Recent alluvial and lacustrine sands, pebbles, clay sands, clay, loam and other
- Q_{IV}^1 — Recent (early) lavas. Andesites, andesite-basalts, volcanic sands of volcano Vayots Dzor
- Q_{III-IV} — Upper Quaternary-Recent sediments. Proluvial-deluvial gravel, screes, pebbles, clay sands
- $\alpha\beta Q_{II}$ — Middle-quaternary andesite-basalts
- αQ_I — Lower-quaternary andesites

Neogene

- N_1^3-$N_2^{1б}$ — Upper Miocene-Lower Pliocene. Upper sequence. Andesites, andesite-dacites
- N_1^3-$N_2^{1\alpha}$ — Upper Miocene-Lower Pliocene. Lower sequence. Volcanic breccias, ashy tuff, liparites, andesites

Paleogene

- ₽$_2^3$ — Upper Eocene-Oligocene. Sandstones. Tuff sandstones, tuff conglomerates, lava breccias, conglomerates, lavas of andesite porphyrites
- ₽$_2^{2б}$ — Tuff sandstone stratum. Tuff sandstones, tuff siltstones, tuffites
- ₽$_2^{2\alpha}$ — Tuffite stratum. Tuff siltstones, tuff sandstones, tuff conglomerates, tuffites. In some places with Interstratal and interformation bodies of andesite, andesite-dacites,

SUBVOLCANIC ROCKS

- $\xi\pi$ ₽$_2^3$, Upper Eocene dacite porphyrites ($\zeta\pi$)
- ₽$_2^2$ ($\delta\pi$, $\gamma\pi$) — Middle-Eocene dioritic porphyrites ($\delta\pi$)

INTRUSIVE ROCKS

- ₽$_3^2$ ($\gamma\xi$, $\gamma\xi\delta$, $\nu\delta$, $\nu\upsilon\xi$, υ) — Late Oligocene quartz syenites, granosyenites ($\gamma\xi$)Granodiorites, granosyenites, diorites, monzonites without dissection ($\gamma\xi\delta$), gabbro, gabbrodiorites ($\nu\delta$), olivinic gabbro, monzonites, anorthosites without dissection ($\nu\upsilon\xi$), anorthosites (υ).
- Diorite-porphyrites (a), gabbro porphyrites (b), dacite porphyrites (c) andesites (d), basalts (e).
- Granites (a), syenites (b), diorites (c), gabbro (d), olivinic gabbro (e), anorthosites (f)
- Clay, sands
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- W A$_1$ K O — Formation of secondary quartzites (Amulsar ridge and other). Monoquartzites ( ), alunite quartzites ( ), kaolinite quartzites ( ), silicification ( ).
- Borders: (a)between formations of different ages, (b) lithological and facial subdivisions of the same age
- Cinder cones (hornito) – volcanic centers with crater
- Falling-landslide formations
- Main dislocations with break of continuity: a) certain, b) inferred, в) identified by aerial surveys
- Faults without considerable displacement
- Place of findings of fossil organic remains (exuviaes)
- Attitude of beds inclined
- Direction of lava flows

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1.3. Mineral composition and qualitative properties

Amulsar deposit ore is represented by mineralized secondary quartzites, and gold and silver grades are the main indicators of their quality. The grades of gold and silver have been tested in several thousand samples. Based on the assay results gold mineralization in the range of occurrence of secondary quartzites is variable and discrete.

It should be noted that any regularity of distribution of poor, medium and relatively rich varieties of ores is not seen within the area of the deposit, which made impossible to present these varieties of ore in separate estimation blocks when contouring the resources.

Besides the metal contents, the feasibility of the specific weight of ore is also important for unbiased qualitative and quantitative assessment of reserves.

During the exploration activities this index has been determined by Geoid LLC.

The specific weight value of 2.37 t/m^3 has been taken as a basis when estimating the reserves of Erato. By the way, the same value was used also for estimating the reserves of Tigranes and Artavazdes/

1.4. Mineral processing description and flowsheet

The scoping for processing the ore of Amulsar deposit has been carried out in several stages by the companies SGS, WAI and KSA.

The tests at KSA proved the identity of technological characteristic of the ores of Erato, Tigranes and Artavazdes and the feasibility of recovery of gold from the ore of Erato by using the heap leach method.

The feasibility of the process flowsheet (heap leaching, Dore) and the following technological parameters have been proved based on the tests at the American KSA:

- Optimum size of ore crushing – 12 mm;
- Cyanide solution concentration – 0.05%;
- Specific consumption of cyanide solution – 0.13 to 0.44 kg/t
- Specific consumption of lime – 0.73 kg/t
- Heap leaching process duration – 40 days;
- Gold recovery from heap leaching of ore – 88.3%;
- Gold grade in heap leach tails – 0.03-0.09 g/t;
- Gold recovery while getting Dore bar from the ore;
- Silver recovery while getting Dore bar from the ore.

1.5. Amulsar ore reserve estimation

1.5.1. Cutoff parameters

The following parameters have been used for contouring the in-balance reserves of both Tigranes and Artavazes and Erato sites:

- cutoff grade of gold in the ore – 0.20 g/t;
- Minimum allowable contour sizes of the mineralized intervals included in reserve estimation, as well as maximum allowable size of off-grade ore and barren rocks is 5.0m.

1.5.2. Results of Amulsar reserve estimation

The resources of Amulsar Gold Deposit have been estimated and approved by sites.

Site Tigranes was the main prospecting project before 2008. C1 + C2 reserves of Tigranes (about 17.4 Mt ore, approximately 16.4 t gold) were approved by decision №211 dated 23.09.2009 of the Agency for Mineral Resources of RA Ministry of Energy and Natural Resources.

Detailed exploration of Site Artavazdes was completed in 2009-2011. Together with Tigranes the Site Artavazdes has been considered as a joint mineralization zone which reserves were approved by the Agency's decision №309 dated 19.09.2011.

Table 1.1 Ore and gold reserves of Amulsar Deposit, Sites Tigranes and Artavazdes

Indices		Unit	Reserve category		
			C_1	C_2	C_1+C_2
Reserves	Ore	t	**27138760**	**29295718**	**56434478**
	Gold	kg	**27078.5**	**25585.5**	**52664.0**
	Silver	kg	**105137.9**	**105369.3**	**210507.2**
Grade	Gold	g/t	**0.998**	**0.873**	**0.933**
	Silver	g/t	**3.87**	**3.60**	**3.73**

Out of the approved reserves the following commercial reserves of C1+C2 categories of ore, gold and silver were contained within the boundaries of the open pit.

Table 1.2

Level	Ore reserves, t	Average grade, g/t		Reserves, kg	
		Au	Ag	Au	Ag
1	2	3	4	5	6
2960	142127	0,688	3,34	97,8	474,2
2950	336341	0,966	7,47	325,0	2513,2
2940	532496	0,702	3,80	373,9	2022,4
1	2	3	4	5	6
2930	887892	0,676	8,13	600,3	7222,7
2920	1129497	1,081	7,92	1221,0	8945,7
2910	1783224	0,798	3,51	1423,3	6265,6
2900	2345413	0,848	3,07	1989,9	7203,1
2890	2478174	1,033	3,23	2560,8	8011,9
2880	2445970	1,020	2,80	2496,2	6839,9
2870	2535734	0,801	3,77	2031,4	9567,5

2860		2771459	1,058	3,57	2931,4	9884,7
2850		2802506	0,909	3,13	2547,2	8768,3
2840		2805369	1,108	3,42	3109,4	9583,0
2830		2762576	0,863	3,79	2383,0	10476,0
2820		2240060	1,044	3,84	2338,1	8603,7
2810		1748136	0,963	4,51	1683,4	7879,3
2800		1527650	1,017	4,70	1553,5	7179,7
2790		1139342	0,961	4,08	1075,7	4565,3
2780		1116934	1,040	4,22	1161,2	4711,5
2770		1124541	1,472	3,18	1655,6	3581,5
2760		660552	0,613	3,22	404,8	2127,9
2750		345389	0,821	3,24	283,5	1120,5
2740		131829	1,258	2,86	165,9	377,3
Total						
C_1+C_2		**35776924**	**0,961**	**3,85**	**34394,92**	**137862,6**
Including	**C_1**	**25629479**	**0,998**	**3,88**	**25571,29**	**99535,5**
	C_2	**10147445**	**0,870**	**3,78**	**8823,64**	**38327,1**

The estimation block areas on horizontal sections have been measured using AutoCad.

In 2012 the Company VHH LLC completed the working design of the Amulsar gold-bearing quartzite deposit. According to the design, the capacity of the open pit by commercial ore is taken:

1-3 years of operation (I phase) – 2.6Mt;

4-6 years of operation (II phase) – 4.0Mt;

Starting from the 7th year of operation (III phase) – 5.5Mt.

Out of the approved reserves totaling 56438478 t only 55644803 t (98.6% of the approved reserves) were included in the final contours of the open pit.

As of 12.09.2013, the reserves of Erato Site of Amulsar gold-bearing quartzite deposit within the limits proved by the authors of the geological report have been approved by Decision №360 dated 11.12.2013 of the Agency for Mineral Resources. They are tabulated below.

Table 1.3 Explored ore and gold reserves of Amulsar deposit, Site Erato

Reserve category	**Reserves**			**Average grades, g/t**	
	Ore, thsd. t	**Gold, kg**	**Silver, t**	**Gold**	**Silver**
C_1	17824.7	11862.5	45.89	0.666	2.57
C_2	15117.1	9206.5	37.97	0.609	2.51
C_1 + C_2	32941.8	21069.0	83.86	0.640	2.55

Total reserves of ore and metals by geological blocks are summarized in Table 1.4. The specific weight value of 2.37 t/m3 has been taken as a basis when estimating the reserves.

Table 1.4. Calculation of ore and metal reserves

Reserve block	Block volume, m^3	Ore-bearing factor	Ore volume, m^3	Ore reserves, t	Grade, g/t		Metal reserves, kg	
					Au	Ag	Au	Ag
1	2	3	4	5	6	7	8	9
Level 2900								
Block 1 – C_1	19524	0.83	16129	38225	1.818	3.49	69.5	133.4
Level 2890								
Block 2 – C_1	67738	0.89	60608	143640	0.922	2.67	132.4	383.5
Level 2880								
Block 3 – C_1	94401	0.88	83073	196883	0.437	2.57	86.0	506.0
Level 2870								
Block 4 – C_1	117012	0.97	113502	268999	0.336	2.39	90.4	642.9
Level 2860								
Block 5 – C_1	129853	1.00	129853	307752	0.541	2.03	166.5	624.7
Level 2850								
Block 6 – C_1	137012	0.90	123311	292247	0.451	2.01	131.8	587.4
Level 2840								
Block 7 – C_1	228526	0.93	212529	503694	0.402	1.85	202.5	931.8
Level 2830								
Block 8 – C_1	344202	0.90	309782	734183	0.752	2.06	552.1	1512.4
Level 2820								
Block 9 – C_1	418770	0.88	368518	873387	0.665	2.33	580.8	2035.0
Level 2810								
Block 10 – C_1	484322	0.84	406830	964188	0.559	2.11	539.0	2034.4
Block 10 – C_2	35175	*0.84*	*29547*	*70026*	*0.559*	*2.11*	*39.1*	*147.8*
Total C_1 + C_2	519497	0.84	436377	1034215	0.559	2.11	578.1	2182.2
Level 2800								
Block 11 – C_1	524557	0.93	487838	1156176	0.472	2.12	545.7	2451.1
Block 11 – C_2	123519	*0.72*	*88950*	*210811*	*0.667*	*3.35*	*140.5*	*706.6*
Total C_1+C_2	648076	0.89	576788	1366987	0.502	2.31	686.2	3157.7
Level 2790								
Block 12 – C_1	456072	0.95	433268	1026846	0.704	2.37	722.9	2433.6
Block 12 – C_2	125054	*0.95*	*118800*	*281557*	*0.648*	*2.42*	*182.5*	*680.4*
Total C_1 + C_2	581126	0.95	552069	1308403	0.692	2.38	905.4	3114.0
Level 2780								
Block 13 – C_1	423303	0.92	389439	922970	0.558	2.27	515.0	2095.1
Block 13 – C_2	63325	*0.92*	*58259*	*138074*	*0.558*	*2.27*	*77.0*	*313.4*
Total C_1 + C_2	486628	0.92	447698	1061044	0.558	2.27	592.1	2408.6
Level 2770								
Block 14 – C_1	487534	0.92	448531	1063019	0.640	2.44	680.3	2593.8
Block 14 – C_2	134758	*0.92*	*123977*	*293826*	*0.585*	*1.89*	*171.8*	*554.1*
Total C_1 + C_2	622292	0.92	572509	1356845	0.628	2.32	852.1	3147.9
Level 2760								
Block 15 – C_1	468533	0.98	459162	1088215	0.751	3.32	817.2	3612.9
Block 15 – C_2	260464	*0.95*	*247966*	*587679*	*0.879*	*3.69*	*516.8*	*2169.0*
Total C_1 + C_2	728997	0.97	707128	1675894	0.796	3.45	1334.0	5781.8

Reserve block	Block volume, m^3	Ore-bearing factor	Ore volume, m^3	Ore reserves, t	Grade, g/t		Metal reserves, kg	
					Au	Ag	Au	Ag
1	2	3	4	5	6	7	8	9
Level 2750								
Block 16 – C_1	343738	0.97	333426	790219	1.103	3.84	871.6	3034.4
Block 16 – C_2	332189	*0.95*	*315464*	*747650*	*1.089*	*3.65*	*813.9*	*2732.6*
Total $C_1 + C_2$	675927	0.96	648890	1537869	1.096	3.75	1685.5	5767.0
Level 2740								
Block 17 – C_1	363221	0.97	352324	835009	0.934	3.44	779.9	2872.4
Block 17 – C_2	309106	*0.97*	*299833*	*710604*	*1.014*	*3.37*	*720.9*	*2398.1*
Total $C_1 + C_2$	672327	0.97	652157	1545613	0.971	3.41	1500.8	5270.5
Level 2730								
Block 18 – C_1	501903	0.91	456732	1082454	0.643	2.91	696.0	3149.9
Block 18 – C_2	388116	*0.84*	*326485*	*773769*	*0.573*	*3.56*	*443.7*	*2752.8*
Total $C_1 + C_2$	890019	0.88	783217	1856224	0.614	3.18	1139.7	5902.8
Level 2720								
Block 19 – C_1	526923	0.95	500577	1186367	0.478	2.76	567.1	3274.4
Block 19 – C_2	463790	*0.93*	*430693*	*1020743*	*0.443*	*2.48*	*452.6*	*2530.3*
Total $C_1 + C_2$	990713	0.94	931270	2207110	0.462	2.63	1019.7	5804.7
Level 2710								
Block 20 – C_1	427947	0.98	419388	993950	0.462	2.32	459.2	2306.0
Block 20 – C_2	*373273*	*0.92*	*341711*	*809997*	*0.384*	*2.28*	*311.1*	*1843.1*
Total $C_1 + C_2$	801220	0.95	761159	1803947	0.427	2.30	770.3	4149.1
Level 2700								
Block 21 – C_1	381552	0.98	373921	886193	0.916	2.44	811.8	2162.3
Block 21 – C_2	413164	*0.96*	*396954*	*940780*	*0.697*	*2.23*	*655.3*	*2094.5*
Total $C_1 + C_2$	794716	0.97	770875	1826973	0.803	2.33	1467.1	4256.8
Level 2690								
Block 22 – C_1	348248	0.86	299493	709799	1.182	2.55	839.0	1810.0
Block 22 – C_2	530517	*0.91*	*482608*	*1143780*	*0.738*	*2.23*	*844.1*	*2545.9*
Total $C_1 + C_2$	878765	0.89	782101	1853579	0.908	2.35	1683.0	4355.9
Level 2680								
Block 23 – C_1	267408	0.90	240667	570381	0.676	2.71	385.6	1545.7
Block 23 – C_2	571902	*0.89*	*506318*	*1199973*	*0.635*	*2.58*	*761.6*	*3092.6*
Total $C_1 + C_2$	839309	0.89	746985	1770354	0.648	2.62	1147.2	4638.3
Level 2670								
Block 24 - C_1	282811	0.94	265842	630046	0.643	3.04	405.1	1915.3
Block 24 – C_2	431378	*0.96*	*412637*	*977950*	*1.034*	*2.94*	*1011.5*	*2876.5*
Total $C_1 + C_2$	714189	0.95	678480	1607997	0.881	2.98	1416.6	4791.8
Level 2660								
Block 25 – C_1	251309	0.94	236230	559866	0.384	2.22	215.0	1242.9
Block 25 – C_2	233176	*0.96*	*224030*	*530952*	*0.407*	*1.85*	*215.9*	*982.4*
Total $C_1 + C_2$	484485	0.95	460261	1090818	0.395	2.04	430.9	2225.3
2600 ÷ 2660 Level								
Block 26 – C_2	2078160	0.95	1974252	4678977	0.395	2.04	1848.2	9545.1
Overall C_1	8096419	0.93	7520973	17824707	0.666	2.57	11862.5	45891.6
Overall C_2	6867066	0.93	6378544	15117148	0.609	2.51	9206.5	37965.3
Overall $C_1 + C_2$	14963485	0.93	13899517	32941855	0.640	2.55	21069.0	83856.9

The original Armenian document has been translated by Lydian into English at the request of the Armenian Corruption, Property Crimes and Cybercrime Investigation Department. If there is any discrepancy between the English and Armenian translation, the Armenian version will prevail as the official document.

Since C2 category reserves have been contoured mainly using the extrapolation method over C1 category reserves and thus they are described by the data of a few exploration cross sections, then their direct calculations could result in big errors in indices. For this reason, the indices corresponding to C1 and C1 + C2 category reserves in Table 1.4 have been given separately by direct calculations, and then based on them the values corresponding to C2 category have been defined, which are given in the table in italic font.

The approved ore reserves of all the sites of Amulsar deposit by C1 + C2 categories are summarized in Table 1.5.

Table 5.

Reserve category	**Reserves**			**Average grades, g/t**	
	Ore, thsd. t	**Gold, kg**	**Silver, t**	**Gold**	**Silver**
C_1	44963.46	38941.0	151.028	0.866	3.036
C_2	44412.82	34792.0	143.339	0.783	3.23
$C_1 + C_2$	89376.28	73733.0	294.367	0.825	3.29

Out of the approved C1 + C2 category reserves the following has been included in the final contours of the open pits under this new working design:

Artavazdes and Tigranes (Open pit 1) – 56434478 t ore (approved reserves in full);

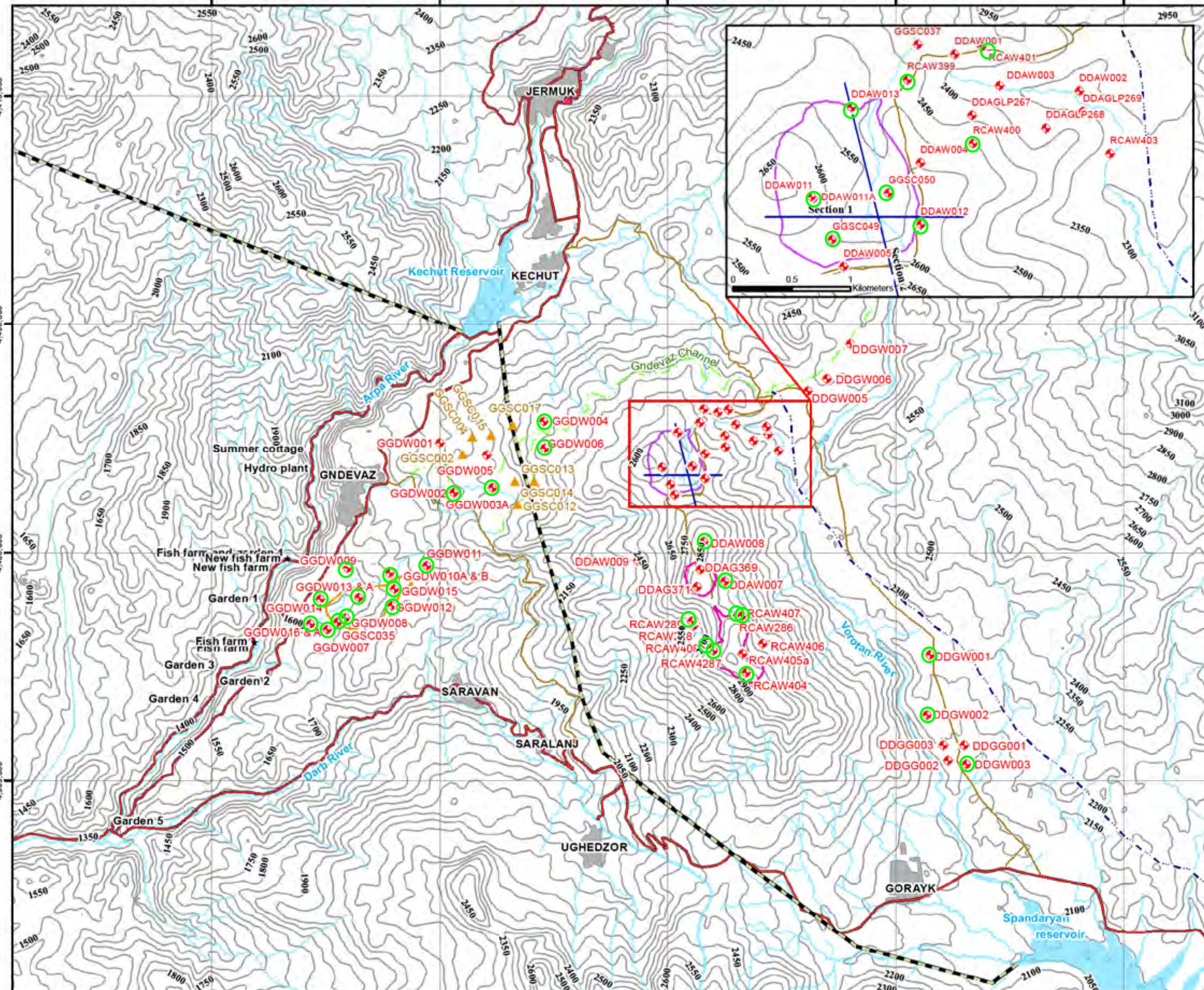
Site Erato (Open pit 2):

I stage - 21972758t (66.7% of approved reserves)

II stage - 10969097t (33.3% of approved reserves).

The first stage open pit contour matches with the open pit contour designed by the authors of the report.

Appendix B: Map Showing Hydraulic Conductivity Test Locations



Legend

Groundwater Level Monitoring Locations

- Groundwater Well
- Open Borehole
- Landmark
- Lines of Section, Drawings 4.8.5 and 4.8.6
- Road
- Gas Pipeline
- Tunnel Arpa Sevan
- Contour (10 metre)

Mine Facilities

- Mine Pit
- Barren Rock Storage Facility
- Heap Leach Facility
- Watercourse
- Town

REFERENCES

Coordinate System: WGS 1984 UTM Zone 38N.
Data provided by client

0 1.5 3 6 Kilometers

SCALE 1:35,000 1 CENTIMETER = 0.35 KILOMETERS WHEN PRODUCED AT SIZE A3

PROJECT	
	AMULSAR GOLD PROJECT ESIA
TITLE	CURRENT AND HISTORICAL GROUNDWATER LEVEL MONITORING LOCATIONS

Golder Associates Bourne End, UK	PROJECT No.		1543827	FILE No.	
	DESIGN	HG	01/07/2014	SCALE AS ABOVE	REV B
	GIS	LD	1/12/2016	DRAWING	
	CHECK	HG	1/12/2016	4.8.1	
	REVIEW	GDLT	1/12/2016		

E:\Data\Lydian_International\Armenia\99_PROJECTS\1543827_ESIA_Addendum\1543827_Dec_2015_v10\02_PRODUCTION\MXD\1543827-CM-4-8-1-Current-and-historical-GW-Level.mxd | 1/12/2016 2:22:08 PM | hgarrick

Appendix C: Lydian's Responses (April 2019) to ELARD Team Inquiry (Geochemical Model Input Data & Phases and Lydian Press Release about Amulsar Mine Groundbreaking)

Letter for SIC

Question

The highlighted question refers to geochemical modeling. An open system exchanges mass within its surroundings (i.e., allows exchange of gases like carbon dioxide (CO2) and oxygen (O2) between the leachate from the rock and the atmosphere). A closed system does not. The question concerns the assumptions and implementation in the water quality modeling used by Lydian. Specifically, we would like to know whether exchange of the atmospheric gases CO2 and O2 was permitted in the Amulsar model. We understand the model used for the Site is equilibrium, for which the modeler can specify as input whether the modeled waters are in equilibrium with the partial pressures of these gases in the atmosphere.

Response

We assumed an open system. Although our cover modeling showed that the BRSF closure cover will limit oxygen diffusion within the BRSF, it is very complicated to model the depletion of oxygen within the rock. As a simplification, it was assumed that the equilibrium would be fully open with respect to atmospheric CO_2 and O_2.

Question

After the heap leaching operations are completed and before the heap is rinsed with fresh water, what happens to the leach solution that has been used for the past ten years. Please describe the process and actions with sufficient details. And, if such action and details have already been provided or included in the ESIA, please advise where in the ESIA (section and appendix) we can find these details.

Response

From ESIA Chapter 3 (Project Description) Section 3.13.3 Site Wide Project Water Balance during Operation (page 3.65).

The Project will discharge no contact water up to Year 4 of operations. From Year 5 , excess contact water may be generated because the Phase 3 HLF increases contact water volumes beyond the consumptive capacity of the HLF, and because the reduced solution application rate decreases water loss in the HLF. The installation of evaporation sprays on the side slope of the heap will be used to evaporate excess solution. The excess contact water not routed back to the HLP will be treated in a passive treatment system (PTS) (see Section 3.13.5).

Further details on the data behind this can be found in the Site Wide Water Balance (previously provided) in sections 6.1.3 and 6.1.4,

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26.04.2019թ.
Հ/Ա-2019/84

ՀՀ քննչական կոմիտեի հատկապես կարևոր գործերի
քննության գլխավոր վարչության կոռուպցիոն, սեփականության ուղղված հանցագործությունների
և կիբեռհանցագործությունների քննության վարչության պետ՝
Յու. Իվանյանին

Ի պատասխան Հատուկ քննչական կոմիտեից ստացված խնդրանքին, «Լիդիան Արմենիա» ընկերության կողմից տրամադրվել է Շրջակա միջավայրի ազդեցության «Ջերմոցային գազերի արտանետումներ և կլիմայի փոփոխություն» անվանմամբ գլուխ 5.1-ը: Պահանջված փաստաթուղթը ներկայացվել է Կոմիտեին 16 ապրիլի 2019թ:

Տվյալ փաստաթղթի հետ կապված Լիդիանը նկատել է հետևյալ անճշտությունը՝
Խմբագրական վրիպակ է հայտնաբերվել այս գլխում ՇՄԱԳ-ի թարգմանված տարբերակի պատրաստման ընթացքում

- Նկ. 5.1.2-ն իրականում ԲՄԱԳ-ի

Head of Corruption, Property Crimes and Cybercrime Investigation Department

Yura Ivanyan

Lydian Armenia provided Chapter 5.1 Greenhouse Gas Emissions and Climate Change of the Environmental Impact Assessment (2016) in response to a request from the Special Investigative Committee. The requested document was submitted to the SIC on 16 April 2019.

With the document Lydian noted the following error:

During preparation of the translation of the EIA an editorial error has been found in this chapter.

- *Figure 5.1.2 Is actually the same figure extracted from two versions of the ESIA (Figure 6.4.2). The top one is from V10 (2016) and the lower from V9 (2015)*
- *Figure 5.1.4 Is actually the same figure extracted from two versions of the ESIA (Figure 6.4.4). The top one is from V9 (2015) and the lower from V10 (2016)*
- *Figure 5.1.3 is taken from v10 of the ESIA (Figure 6.4.3)*

Lydian included this translation error to maintain full transparency with respect. The EIA was being drafted as the ESIA was being finalised. This երկու տարբերակներից վերցված նկար է (Նկ. 6.4.2): Վերևի նկարը վերցված է ԲՍԱԳ-ի 10-րդ տարբերակից (v10, 2016թ.), իսկ ներքևինը՝ 9-րդ տարբերակից (v9, 2015թ.)

- Նկ. 5.1.4-ն իրականում ԲՍԱԳ-ի երկու տարբերակներից վերցված նկար է (Նկ. 6.4.4): Վերևի նկարը վերցված է ԲՍԱԳ-ի 9-րդ տարբերակից (v9, 2015թ.), իսկ ներքևինը՝ 10-րդ տարբերակից (v10, 2016թ.)
- 5.1.3 նկարը վերցվել է ԲՍԱԳ-ի 10-րդ տարբերակից (Նկ. 6.4.3)

Թարգմանչական այս վրիպակը նշվում է ՇՄԱԳ-ի թարգմանված փաստաթղթերի ամբողջական թափանցիկությունն ապահովելու նպատակով: Քանի որ ՇՄԱԳ-ը կազմվել է ԲՍԱԳ-ի լրամշակման ընթացքում, ապա ՇՄԱԳ-ում սխալմամբ ներառվել են աղյուսակներ ինչպես ԲՍԱԳ—ի տարբերակ 9-ից, այնպես էլ տարբերակ 10-ից: Սակայն միևնույն գրաֆիկի երկու տարբերակների ներառումը որևէ կերպ չի ազդել կամ փոփոխել Ծրագրի գնահատման ընթացքն ու արդյունքները:

Լրացուցիչ հարցերի կամ պարզաբանումների անհրաժեշտության դեպքում, խնդրում ենք դիմել մեզ:

resulted in tables from both v9 and v10 of the ESIA being inadvertently included in the EIA. The inclusion of the two sets of graphs does not, in any way, affect or change the outcome of the assessment of the Project.

Should you have any further questions, or require further clarification, then please do not hesitate to ask.

Հարգանքով՝
«Լիդիան Արմենիա» ՓԲ ընկերության կայուն զարգացման գծով փոխնախագահ
Արմեն Ստեփանյան

ԼԻԴԻԱՆ ԱՐՄԵՆԻԱ

26.04.2019թ.
Հ/Ա-2019/85

ՀՀ քննչական կոմիտեի հատկապես կարևոր գործերի
քննության գլխավոր վարչության
կոռուպցիոն, սեփականության ուղղված հանցագործությունների
և կիբեռհանցագործությունների քննության վարչության պետ՝
Յու. Իվանյանին

Հարգելի պարոն Իվանյան,

Սույնով հայտնում ենք, որ Ամուլսարի ոսկու ծրագրի շինարարությունը մեկնարկել է 2016թ. օգոստոսի 19-ին: Կից ներկայացնում ենք շինարարության մեկնարկի վերաբեյալ տեղեկությունը:

Հարգանքով
Լիդիան Արմենիա ՓԲԸ կայուն զարգացման գծով փոխնախագահ՝
Ա. Ստեփանյան

Attn: Head of Corruption, Property Crimes and Cybercrime Investigation Department
Yura Ivanyan

Dear Mr. Ivanyan,

Hereby we submit the information on Amulsar Project groundbreaking event that took place on August 19, 2016.

Kind regards
Lydian Armenia Sustainability VP
Armen Stepanyan

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Amulsar project Groundbreaking Event

On August 19, a Ground-breaking ceremony for Lydian Armenia's Amulsar project took place in the future area of the heap leach facility, at Vayots Dzor Marz of Armenia.

The ceremony was attended by the Prime Minister of Armenia Mr. Hovik Abrahamyan, Minister of Energy and Natural Resources L. Yolyan, Minister of Economy A. Minasyan, heads of communities of Jermuk, Gndevaz, Saravan and Gorayk. Lydian board of directors, several shareholders, representatives of EBRD and IFC, heads of Yerevan offices of the World Bank Mrs. Laura Bailey and IMF Mrs. Teresa Daban Sanchez also attended the ceremony. Ambassador of the USA in Armenia Mr. Richard Mills and (http://www.lydianarmenia.am/img/news/1471965832,33.jpeg) Ambassador of the UK in Armenia Mrs. Judith Farnworth were also present at this milestone event.

Addressing more than 100 guests, community members and Lydian staff Lydian President and CEO Mr. Howard Stevenson welcomed all guests to this new and exciting phase of Amulsar project. He conveyed his gratitude to the Government of Armenia, the communities, heads of diplomatic missions for trust and continuous support. "We know what motivates you is the desire to see a different, better mining operation in Armenia. I want to assure we will do our best to show that there is a different way of doing business, that mining can be responsible, that mining can be safe and that it can benefit the people around the mine. We are here to make it happen during the next 12 years together with all of you".

In his speech Prime Minister of Armenia Mr. Hovik Abrahamyan noted:

"From day one we have greatly supported Amulsar project and we are sure it will be successfully implemented. We have come a long way, we had objective and subjective difficulties but importantly this groundbreaking is taking place today for which I am very glad as the head of the Government. With the decline in foreign investments the launch of such a large scale project is essential. I especially want to welcome the participation of IFIs, particularly IFC and EBRD in the project. I am confident that Amulsar project will create new opportunities for the economic development of Armenia."

On the occasion of the start of construction of Amulsar project Ambassador of the United States in Armenia Mr. Richard Mills conveyed a message which reads: "We congratulate Lydian on this remarkable milestone and welcome the Amulsar project to the country, which will help strengthen the Armenian economy. We are pleased with Lydian's involvement, as a member of the AmCham and a member of the Extractive Industries Transparency Initiative (EITI) working group, in creating a level business playing field and strengthening a strong social corporate responsibility culture here in Armenia. We trust the company will continue to serve as an example of responsible mining, operating transparently in line with international environmental and social standards."

In her message Ambassador of the UK to Armenia Mrs. Judith Farnworth noted: ""This is a groundbreaking event not just for Lydian but also for Armenia. I congratulate Lydian and their many Armenian partners for their years of hard work to reach this momentous day. I think one of the keys to this success is the dialogue which Lydian has conducted: with the Armenian government, local authorities, civil society and perhaps most crucially with the local communities. Through this engagement Lydian has provided assurances that it is committed to responsible mining, bringing economic and social benefits to Armenia whilst respecting the importance of environmental protection.

This approach embodies the principles of the Extractive Industries Transparency Initiative (EITI). We welcome Armenia's commitment to join EITI and are confident that Lydian will play a constructive role as a member of the Multi Stakeholder Group. The UK Embassy stands ready to continue our support to Armenia in its efforts to attain this global standard to promote the open and accountable management of natural resources by sharing UK experience and expertise. We believe Armenia's membership of EITI will boost investor confidence in Armenia's mining sector and attract new interest from domestic and overseas investors. The British Embassy will also continue to work with the Government of Armenia and industry in other sectors to help improve the business climate and promote economic reform in Armenia for the benefit of all."

Amulsar project is going to be the largest investment project in Armenia, planning to invest 370 million USD into the project construction (2016-2018). At peak construction up to 1300 jobs will be secured, while during 10 years of production up to 700 people will be employed directly by Lydian Armenia.

Amulsar project is the first project in Armenia to have produced an Environmental and Social Impact Assessment compliant with IFC and EBRD Performance Standards and Requirements.

In his speech Lydian Armenia General Manager Mr. Hayk Aloyan reiterated the company's commitment to build and operate the project in line with good Industry practice, to benefit the country and the company shareholders.

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We Are Social

(https://[illegible]/channel/UC3FdEw6IQj16k3JSb5-beta/132[illegible])

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ՀՀ քննչական կոմիտեի հատկապես կարևոր գործերի
քննության գլխավոր վարչության
կոռուպցիոն, սեփականության ուղղված հանցագործությունների
և կիբեռհանցագործությունների քննության վարչության պետ՝
Յու. Իվանյանին

Head of Corruption, Property Crimes and Cybercrime Investigation Department
To Mr. Yura Ivanyan

Հարգելի պարոն Իվանյան,

Յուրի Իվանյանը «Լիդիա Արմենիա» ընկերությունից պահանջել է տրամադրել պատասխաններ Ամուլսարի ոսկու հանքի ծրագրի ԴԱԼ-ի և բացահանքերի հոսակորուստների վերաբերյալ՝ «ELARD» ընկերության կողմից բարձրացված մի շարք հարցերին: Սույն նամակն ու դրան կից ներկայացված փաստաթղթերը Լիդիանի պատասխաններն են նշված հարցերին: Դրանք նաև հիմնավորող տվյալներ են, որոնք, մեր կարծիքով, կօգնեն ԷԼԱՐԴ-ին առավել լավ պատկերացում կազմել տվյալ հարցերի վերաբերյալ

Dear Mr. Ivanyan

Lydian Armenia were requested by Yura Ivanyan to provide answers to a number of queries raised by ELARD relating to **BRSF and Pit Seepage Water** aspects of the Amulsar Gold Project.

This letter, and its attachments provide the Lydian responses to those questions as well as supporting information where we believe it add to the understanding of ELARD.

:

ELARD Question/Comments	**Lydian Response**	**Supporting documentation**
BRSF and Pit Seepage Water		

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We need a description of what is being modelled,		
Sources of water input, including water quality for each source and mixing ratios	See attached memos	Pit Backfill Seepage and Water Quality Model Results_v1 Pit Surface Water Quality Memo_14JUL14
Description of the processes causing changes in the water quality (e.g., flow through the rock in the BRSF resulting in adsorption, precipitation onto the rock surfaces	Equilibrium processes. Precipitation processes. No adsorption considered. Please keep in mind that more complicated geochemical models do not necessary result in better simulations. GRE used a field-data-based approach but still included equilibrium and precipitation. In summary, this is a more complicated mixing model that what was performed by Golder in the groundwater model and in the assessment of the impacts to local water bodies. In GRE's simulations, acid-base reactions, precipitation, and dissolution reactions can occur as solutions based on direct field or laboratory measurements come in contact with each other.	
A discussion of how much pyrite oxidation has been included in developing the input water quality description	The pyrite oxidation was taken as an empirical factor based on humidity cell test results.	
Required model details		
What is the pH of the water?	Variable	See attached memos

Are the systems modelled as open or closed?	Can you please elaborate on this question? – open and closed with respect to what?	
Are the solutions in equilibrium with atmospheric CO_2 and O_2? Are pH and pe specified?	They are specified in the pre-mix solutions.	
What is the log of the activities of CO_2 and O_2?	The geochemical mixing models cover the solution transport either within the BRSF or within the pit walls. Both of these systems were assumed to be in equilibrium with CO2 and O2 within the vadose zone of the barren rock, or in the pit backfill. See embedded table below, it's the equilibrium mix table associated with the PHREEQCI model.	

Name	Saturation Index	Moles	Precipitation Only
Alunite	0	0	TRUE
Basaluminite	0	0	TRUE
Birnessite	0	0	TRUE
Boehmite	0	0	TRUE
CO2(g)	-3.5	1	
CupricFerrite	0	0	TRUE
CuprousFerrite	0	0	TRUE
Diaspore	0	0	TRUE
Fe(OH)2.7Cl.3	0	0	TRUE
Fe(OH)3(a)	0	0	TRUE
Gibbsite	0	0	TRUE
Goethite	0	0	TRUE
Hematite	0	0	TRUE
Jarosite(ss)	0	0	TRUE
Jarosite-K	0	0	TRUE
Maghemite	0	0	TRUE
Magnetite	0	0	TRUE
Nsutite	0	0	TRUE

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	O2(g)	-0.67	1		
	Plumbogummite	0	0	TRUE	
	Pyrolusite	0	0	TRUE	
	Strengite	0	0	TRUE	

What is the solution temperature?	25 degrees C. This is not considered to be a sensitive factor	
What redox couple was specified?	We assumed an ARD source taken from the K-cells - and for simplicity only did equilibrium reactions	
What database was used, MinteqA2 or PHREEQC? Or a modified database?	Minteq.v4.dat 11091 2016-04-21	
Is evapoconcentration simulated?	This is not necessary. Please consider that all solutions are immediately treated or consumed – apart from groundwater which will not evapo-concentrate	
Which phases with a saturation index greater than 1 are specified to precipitate?	See table above, all phases listed as TRUE	
Is sorption to hydrous ferric oxide simulated? Number of surface sites and surface area? Are any ions omitted from sorption	It is not. This is a conservative estimate of metals concentration because sorption to ferric iron is not included.	
The modelling shows a quantitative replacement of the ferrous iron seen in the humidity cells water being replaced by aluminum in the BRSF seepage. What	We do not believe you are seeing replacement. We believe we are seeing precipitation of the iron as ferric iron.	

reactions account for this replacement?		
Concentrations of all the major ions in water so that we can do a charge (anion-cation) balance!	All anion-cation balances in the resultant solutions are less than 5%. GRE can provide a tour of the PHREEQC models if requested.	
Heap Leach Facility (HLF) - Barren Leach Solution (BLS))		
During operations, the BLS has been in circulation through the ore pile for 10 years, with several reagents added in each cycle, yet, the predicted water quality given in Table 2 of the Hydrogeologic Risk Assessment - Proposed HLF (the BLS and Detoxified Solution Analysis) seems relatively clean.		
Is this water quality the result of geochemical modelling? And, if so, the same questions as BRSF/Pit water modelling above apply and need Lydian's input. If not, what was the basis for the projected water quality	No, it is the result of laboratory work undertaken by SGS	Kappes, Cassidy Associates report is provided
Some parameter concentrations in the Table are questionable. Was the Table checked for typographical errors or verified with the lab?	Yes, the table was checked, but the data was not cross checked with the laboratory by Golder Associates. The original source for the data was Kappes, Cassidy Associates (2013) and the data was included in the projects 43-101 Feasibility Study (SGS, 2015).	Kappes, Cassidy Associates report is provided
Finally, it is somewhat unclear from the reports as to what happens to the leach solution itself after closure. What is the fate of	It goes into its own passive treatment system. *'Geochemical modeling and prediction of post-closure HLF drain down flow will be advanced during the mine life with the results included in future RC&R Plan*	Section 3.2.7.5 of ESIA Appendix 8.18 the Preliminary Mine Reclamation, Closure and Rehabilitation Plan

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the barren solution used in the HLF after closure?	*updates. It is anticipated that future drain down modeling and geochemical characterization data will be used to optimize the passive treatment process.'*	

Այս հնարավորությունից օգտվելով կցանկանայինք բոլոր ընթերցողներին հիշեցնել, որ ՇՄԱԳ/ԲՍԱԳ-ի շրջանակներում ԴԱԼ-ի նախագծի հետ կապված այս աշխատանքը հիմնված է եղել 2014թ. առկա տվյալների վրա, և ըստ գնահատման, դատարկ ապարների մոտ 40%-ը պոտենցիալ թթվագոյացնող են: Սակայն, ԹԱԴ Բլոկի մոդելի հիման վրա հետագայում կատարված (նախկինում ներկայացված) գնահատումները ցույց տվեցին, որ ՊԹԳ նյութի քանակությունն իրականում մոտ 11% է, և հետևաբար, արտահոսքի մոդելավորման մեջ կիրառված համամասնականության գործակիցը հնացած է, սակայն, կարևոր է նշել, այն նաև «հատկապես պահպանողական է» մոդելի կանխատեսումների առումով:

We would also like to take this opportunity to reiterate to all readers that the work completed with respect to the design of the BRSF for the EIA/ESIA was based on data available in 2014 and included an estimate that 40% percent of waste rock material was potentially acid generating (PAG) material. However, following further evaluation of the PAG material using the ARD Block Model (previously submitted) the estimated amount of PAG material is actually nearer 11% and therefore all mixing factors used in the seepage modelling are essentially obsolete, but importantly also "extra conservative" with respect to the model predictions.

Հարգանքով՝
«Լիդիան Արմենիա» ՓԲ ընկերության կայուն զարգացման գծով փոխնախագահ
Արմեն Ստեփանյան

"Lydian Armenia" CJSC Vice President of Sustainability
Armen Stepanyan