Report to:

Silver Bear Resources Inc.

# NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation

Document No. 1454430200-REP-R0004-00

Report to:

# SILVER BEAR RESOURCES INC.

# NI 43-101 TECHNICAL REPORT FEASIBILITY STUDY UPDATE, MANGAZEISKY SILVER PROJECT, REPUBLIC OF SAKHA (YAKUTIA), RUSSIAN FEDERATION

EFFECTIVE DATE: 4TH OCTOBER 2016


Prepared by Anton von Wielligh, BSc (Hons), PrEng, ECSA, MSAIMM
Arunasalam Vathavooran, PhD., CEng, MIMMM
Damian Hicks, MIEAust CPEng
Derek Chubb, P.Eng.
Guy Roemer, PE
Houcyne El Idrysy, PhD, CGeol, FGS
Jacques du Toit, CEng, PrEng, MScEng, PMP
Krysztof Czajewski, BSc, P.Eng.
Laszlo Bodi, MSc, CEng, P.Eng.
Max Brown, BSc, MSc, CEng, MIMMM
Rene Gharapetian, P.Eng.
Robert Davies, BSc (Hons), CGeol, EurGeol, FGS
Sabry Abdel Hafez, PhD, P.Eng.
Saunjay Duggal, MSc, P.Eng.

JdT/VC

TETRA TECH

Ground Floor, Unit 2, Apple Walk, Kembrey Park, Swindon, SN2 8BL United Kingdom
Phone : +44 1793 512305 www.tetratech.com

# TABLE OF CONTENTS

1.0 SUMMARY ..... 1-1
1.1 INTRODUCTION ..... 1-1
1.2 PROPERTY DESCRIPTION AND LOCATION ..... 1-3
1.3 GEOLOGY AND MINERALIZATION ..... 1-5
1.3.1 REGIONAL GEOLOGY ..... 1-5
1.3.2 PROPERTY GEOLOGY ..... 1-6
1.3.3 MINERALISATION ..... 1-7
1.4 EXPLORATION ..... 1-8
1.5 DRILLING ..... 1-9
1.6 MINERAL PROCESSING AND METALLURGICAL TESTING ..... 1-9
1.7 MINERAL RESOURCE ESTIMATES ..... 1-10
1.7.1 MINERAL RESOURCE STATEMENT ..... 1-10
1.7.2 SUMMARY OF ESTIMATION TECHNIQUES ..... 1-12
1.8 MINERAL RESERVE ESTIMATES ..... 1-13
1.9 MINING METHODS ..... 1-13
1.9.1 OPEN PIT ..... 1-13
1.9.2 UNDERGROUND MINING ..... 1-14
1.10 RECOVERY METHODS ..... 1-15
1.11 PROJECT INFRASTRUCTURE ..... 1-16
1.11.1 GENERAL ..... 1-16
1.11.2 TAILINGS MANAGEMENT FACILITY ..... 1-17
1.11.3 WINTER ROAD ..... 1-20
1.12 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT ..... 1-20
1.13 CAPITAL AND OPERATING COST ESTIMATES ..... 1-21
1.13.1 CAPITAL COST ESTIMATE ..... 1-21
1.13.2 OPERATING COST ESTIMATE ..... 1-21
1.14 ECONOMIC ANALYSIS ..... 1-22
1.15 PROJECT EXECUTION PLAN ..... 1-23
1.16 RISKS AND OPPORTUNITIES ..... 1-23
1.16.1 RISKS ..... 1-23
1.16.2 OPPORTUNITIES ..... 1-24
1.17 RECOMMENDATIONS ..... 1-25
2.0 INTRODUCTION ..... 2-1
3.0 RELIANCE ON OTHER EXPERTS ..... 3-1
3.1 GEOLOGICAL RELIANCE ..... 3-1
3.2 ECONOMIC RELIANCE ..... 3-1
4.0 PROPERTY DESCRIPTION AND LOCATION ..... 4-1
4.1 LOCATION ..... 4-1
4.2 DESCRIPTION ..... 4-2

4.3 HISTORY OF PROPERTY ACQUISITION ..... 4-3
4.4 SURFACE RIGHTS ..... 4-4
4.5 ENVIRONMENTAL LIABILITIES ..... 4-5

5.0 ACCESSIBILITY, CLIMATE, INFRASTRUCTURE, LOCAL RESOURCES AND PHYSIOGRAPHY ..... 5-1

5.1 ACCESSIBILITY ..... 5-1
5.2 CLIMATE ..... 5-2
5.3 INFRASTRUCTURE ..... 5-2
5.3.1 ROADS ..... 5-2
5.3.2 AIR TRANSPORT ..... 5-4
5.3.3 RAIL AND PORTS ..... 5-4
5.3.4 POWER ..... 5-4
5.4 LOCAL RESOURCES ..... 5-5
5.5 PHYSIOGRAPHY ..... 5-5

6.0 HISTORY ..... 6-1

6.1 EXPLORATION HISTORY ..... 6-1
6.1.1 GENERAL EXPLORATION HISTORY TO 2004 ..... 6-1
6.1.2 METALLURGICAL TEST WORK AND RECOVERABILITY ..... 6-2
6.2 HISTORICAL RESOURCE ESTIMATES ..... 6-3
6.2.1 HISTORICAL NON-COMPLIANT RESOURCE ESTIMATES ..... 6-3
6.2.2 HISTORIC NI 43-101 COMPLIANT RESOURCE ESTIMATES ..... 6-6
6.3 HISTORICAL PRODUCTION ..... 6-7

7.0 GEOLOGICAL SETTING AND MINERALIZATION ..... 7-1

7.1 REGIONAL GEOLOGY ..... 7-1
7.2 PROPERTY GEOLOGY ..... 7-2
7.3 MINERALISATION ..... 7-3
7.3.1 MANGAZEISKY ..... 7-6
7.3.2 VERTIKALNY ..... 7-7
7.3.3 ZABYTY AND ZABYTY-2 ..... 7-9
7.3.4 KIS-KUEL ..... 7-10
7.3.5 OROGONDIA ..... 7-10
7.3.6 STERZHNEVOY ..... 7-11
7.3.7 MUKHALKANSKY ..... 7-11
7.3.8 BEZYMYANNY ..... 7-11
7.3.9 NIZHNY ENDYBAL ..... 7-12
7.3.10 VERKHNE ENDYBAL ..... 7-16
7.3.11 PORFIROVY ..... 7-16
7.3.12 BORISOVSKY ..... 7-17

8.0 DEPOSIT TYPES ..... 8-1

8.1 GEOLOGICAL CONCEPTS BEHIND EXPLORATION PROGRAMME ..... 8-2

9.0 EXPLORATION ..... 9-1

9.1 2004 TO 2010 EXPLORATION PROGRAMME SUMMARY ..... 9-1
9.2 2011 AND 2012 EXPLORATION PROGRAMME ..... 9-1
9.3 2013 EXPLORATION PROGRAMME ..... 9-2
9.4 2014 EXPLORATION PROGRAMME ..... 9-5

9.5 2015 EXPLORATION PROGRAMME ..... 9-6
9.6 TRENCH SAMPLING PROCEDURES ..... 9-6
9.1 TETRA TECH OPINION ..... 9-8

10.0 DRILLING ..... 10-1

10.1 DRILLING PROGRAMME 2015 ..... 10-1
10.1.1 VERTIKALNY DEPOSITS ..... 10-1
10.1.2 DRILLING METHODS ..... 10-4
10.2 DOWN HOLE DIRECTIONAL SURVEY METHODOLOGY ..... 10-6
10.3 DRILLHOLE COLLAR SURVEY METHODOLOGY ..... 10-6
10.4 DRILL RIG SETUP ..... 10-7
10.5 DRILLING, CORE HANDLING AND CORE BOX MARK-UP ..... 10-7
10.6 GEOTECHNCIAL LOGGING OF CORE SAMPLES ..... 10-9
10.7 CORE PHOTOGRAPHY ..... 10-10
10.8 GEOLOGICAL LOGGING OF CORE SAMPLES ..... 10-12
10.1 SAMPLING DISCUSSION ..... 10-13
10.1.1 VERTIKALNY ..... 10-13
10.2 TETRA TECH OPINION ..... 10-16

11.0 SAMPLE PREPARATION, ANALYSES AND SECURITY ..... 11-1

11.1 SAMPLE PREPARATION AND ANALYSES ..... 11-1
11.1.1 LABORATORIES ..... 11-4
11.1.2 ASSAYING ..... 11-4
11.1.3 QUALITY ASSURANCE/QUALITY CONTROL ..... 11-4
11.1.4 VERTIKALNY QA/QC ..... 11-5
11.1.5 NIZHNY ENDYBAL QA/QC ..... 11-12
11.1.6 MANGAZEISKY NORTH DEPOSITS QA/QC ..... 11-14
11.2 SECURITY ..... 11-18
11.3 TETRA TECH OPINION ..... 11-18

12.0 DATA VERIFICATION ..... 12-1

12.1 TETRA TECH SITE VISIT ..... 12-1
12.1.1 TETRA TECH AUGUST 2015 SITE VISIT ..... 12-1
12.1.2 DRILLHOLE LOCATIONS ..... 12-1
12.1.3 INDEPENDENT CHECK SAMPLES ..... 12-3
12.1.4 CORE LOGGING AND SAMPLING ..... 12-3
12.3 OFFICE BASED DATA VERIFICATION ..... 12-8
12.3.1 ASSAY CERTIFICATES ..... 12-8

13.0 MINERAL PROCESSING AND METALLURGICAL TESTING ..... 13-1

13.1 SUMMARY ..... 13-1
13.2 HISTORICAL TEST WORK REVIEW ..... 13-1
13.2.1 TSNIGRI TEST WORK RESULTS (2008) ..... 13-1
13.2.2 GINTSVETMET TEST WORK RESULTS (2011) ..... 13-4
13.2.3 CONCLUSIONS OF HISTORICAL WORK ..... 13-7
13.3 FEASIBILITY STUDY TEST WORK (SGS VOSTOK 2014) ..... 13-8
13.3.1 METALLURGICAL SAMPLING ..... 13-8
13.3.2 MINERALOGICAL TEST WORK ..... 13-13
13.3.3 METALLURGICAL TEST WORK ..... 13-16

13.4 LEACH VARIABILITY TEST WORK (TOMS) ..... 13-41
13.4.1 SAMPLE BACKGROUND AND SELECTION ..... 13-41
13.4.2 SAMPLE PREPARATION ..... 13-42
13.4.3 HEAD ASSAYS ..... 13-42
13.4.4 LEACH TESTS ..... 13-43
13.4.5 RESULTS ..... 13-44
13.5 PRIMARY ORE TEST WORK (TOMS) ..... 13-45
13.5.1 SAMPLE BACKGROUND ..... 13-45
13.5.2 SAMPLE PREPARATION ..... 13-46
13.5.3 HEAD ASSAYS ..... 13-46
13.5.4 MINERALOGICAL ANALYSIS ..... 13-47
13.5.5 BOND BALL MIL INDEX TEST ..... 13-48
13.5.6 CYANIDE LEACH TESTS ..... 13-48
13.5.7 FLOTATION TEST WORK ..... 13-55
13.6 PROCESS SELECTION AND FLOWSHEET DEVELOPMENT ..... 13-58
13.6.1 OXIDE ORE PROCESSING ..... 13-58
13.6.2 PRIMARY ORE PROCESSING ..... 13-59
13.7 METALLURGICAL RECOVERY ..... 13-59
13.7.1 OXIDE ORE RECOVERY ..... 13-60
13.7.2 PRIMARY ORE RECOVERY ..... 13-61
14.0 MINERAL RESOURCE ESTIMATES ..... 14-1
14.1 SUMMARY ..... 14-1
14.1.1 SUMMARY OF ESTIMATION TECHNIQUES ..... 14-1
14.2 DATABASE ..... 14-2
14.3 GEOLOGICAL INTERPRETATION ..... 14-3
14.3.1 STRONGLY MINERALISED ZONE ..... 14-3
14.3.2 SUBORDINATE PARALLEL AND OBLIQUE VEINS ..... 14-3
14.3.3 WIREFRAME MODELLING ..... 14-4
14.4 EXPLORATORY DATA ANALYSIS/DOMAINING ..... 14-7
14.4.1 RAW DRILLHOLE STATISTICS ..... 14-7
14.4.2 SAMPLE LENGTH AND COMPOSITING ..... 14-11
14.4.3 TOP CUTS ..... 14-15
14.5 DENSITY ..... 14-16
14.6 VARIOGRAPHY ..... 14-17
14.7 RESOURCE BLOCK MODELS ..... 14-19
14.7.1 INTERPOLATION STRATEGY ..... 14-20
14.8 BLOCK MODEL VALIDATION ..... 14-21
14.8.2 CONCLUSION ..... 14-26
14.10 MINERAL RESOURCE TABULATION ..... 14-28
14.10.1 CUT-OFF GRADES ..... 14-28
14.10.3 GRADE TONNAGE SENSITIVITY ..... 14-30
15.0 MINERAL RESERVE ESTIMATES ..... 15-1
15.1 CUT-OFF GRADE PARAMETERS ..... 15-1
15.1.1 OPEN PIT MINERAL RESERVE CUT-OFF ..... 15-1
15.1.2 UNDERGROUND MINERAL RESERVE CUT-OFF ..... 15-2
15.2 MINERAL RESERVE STATEMENT ..... 15-3
16.0 MINING METHODS ..... 16-1
16.1 OPEN PIT MINING ..... 16-1

16.1.1 Open Pit Mining Method Selection ..... 16-1
16.1.2 Pit Slope Characterisation ..... 16-1
16.1.3 Pit Optimisation ..... 16-2
16.1.4 Open Pit Mine Design ..... 16-8
16.1.6 Open Pit Schedule ..... 16-14
16.1.7 Open Pit Mine Operations ..... 16-22
16.2 Underground Mining ..... 16-27
16.2.1 Underground Mining Method Selection ..... 16-27
16.2.2 Optimisation ..... 16-28
16.2.3 Geotechnical Characterisation ..... 16-28
16.2.4 Hydrological and Hydrogeological Characterisation ..... 16-28
16.2.5 Underground Mine Design ..... 16-29
16.2.6 Underground Mine Services ..... 16-36
16.2.7 Mine Development Schedule ..... 16-39
16.2.8 Mine Production Schedule ..... 16-44
16.2.9 Underground Mining Equipment ..... 16-47
16.2.10 Underground Mine Operations ..... 16-47
16.3 Mine Closure ..... 16-49
17.0 RECOVERY METHODS ..... 17-1
17.6 Process description ..... 17-9
17.6.1 Process Description Overview ..... 17-9
17.6.2 Crushing ..... 17-10
17.6.3 Milling and Gravity ..... 17-11
17.6.4 Leaching ..... 17-12
17.6.5 Dewatering, Filtration and Clarification ..... 17-13
17.6.6 Direct Electrowinning ..... 17-13
17.7 Plant Services and Reagents ..... 17-15
17.7.1 Water ..... 17-15
17.7.2 Cyanide and Lime ..... 17-15
17.8 Control Philosophy ..... 17-16
18.0 PROJECT INFRASTRUCTURE ..... 18-1
18.1 Overview ..... 18-1
18.2 Logistical Infrastructure ..... 18-2
18.2.1 Ports ..... 18-2
18.2.2 Rail ..... 18-2
18.2.3 Access Roads ..... 18-2
18.3 Site Layout ..... 18-8
18.3.1 Site Layout Design Basis ..... 18-8
18.4 Site Geotechnical ..... 18-12
18.4.1 Old Camp Site and Airstrip ..... 18-12
18.4.2 New Camp Site and Storage Areas ..... 18-13
18.4.3 Process Plant and TMF Areas ..... 18-16
18.4.4 Conclusions ..... 18-20
18.5 Design Basis ..... 18-22
18.5.1 Structural Design Basis ..... 18-22
18.5.2 Project Seismic Characteristics ..... 18-28
18.5.3 Architectural Design Basis ..... 18-30
18.6 Site Roads ..... 18-30
18.6.1 Access from Airstrip to Camp ..... 18-30

18.6.2 INTERNAL ROADS ..... 18-32
18.6.3 VEHICLE TYPES ..... 18-36
18.7 PROCESSING FACILITY ..... 18-37
18.7.1 GENERAL APPROACH ..... 18-37
18.7.2 PROCESS PLANT BUILDING ..... 18-38
18.7.3 ROM PAD AND CRUSHING ..... 18-40
18.7.4 THE MILL ..... 18-40
18.7.5 TAILINGS HANDLING ..... 18-45
18.7.6 PLANT SERVICES ..... 18-45
18.7.7 PROCESS INSTRUMENTATION AND CONTROLS ..... 18-47
18.7.8 PROCESSING FACILITY CLOSURE PLAN ..... 18-47
18.8 SITE FACILITIES ..... 18-47
18.8.1 GARAGE/WAREHOUSE ..... 18-47
18.8.2 FIRE STATION ..... 18-48
18.8.3 OPERATION AND CONSTRUCTION CAMP ACCOMMODATION ..... 18-48
18.8.4 AIRSTRIP ..... 18-49
18.8.6 SITE FACILITIES CLOSURE PLAN ..... 18-49
18.9 REMOTE SITE FACILITIES ..... 18-49
18.9.1 OFFICES ..... 18-49
18.9.2 REFINERY ..... 18-49
18.10 TAILINGS MANAGEMENT FACILITY ..... 18-50
18.10.1 TAILINGS PROPERTIES ..... 18-50
18.10.2 TMF DESIGN ..... 18-50
18.10.3 TMF OPERATIONS STRATEGY ..... 18-51
18.10.4 CLOSURE AND REHABILITATION PLAN ..... 18-51
18.11 WASTE ROCK DUMP, ORE STOCKPILE AND OVERBURDEN STORAGE AREA ..... 18-52
18.11.1 ORE STOCKPILE ..... 18-53
18.11.2 OVERBURDEN STOCKPILE ..... 18-53
18.11.3 WASTE ROCK DUMP ..... 18-54
18.11.4 WASTE ROCK DUMP, ORE STOCKPILE AND OVERBURDEN STOCKPILE CLOSURE PLAN ..... 18-59
18.12 SITE WATER MANAGEMENT ..... 18-59
18.12.1 CLIMATE ..... 18-59
18.12.2 SURFACE WATER ..... 18-61
18.12.3 PROJECT STAFF ..... 18-62
18.12.4 ORE PROCESSING ..... 18-62
18.12.5 SUBSURFACE MINING ..... 18-63
18.12.6 CALCULATIONS ..... 18-63
18.12.7 OUTPUTS ..... 18-64
18.12.8 ASSUMPTIONS ..... 18-64
18.12.9 RESULTS ..... 18-65
18.13 WASTE AND SEWAGE ..... 18-67
18.14 SITE STORAGE ..... 18-68
18.14.1 REAGENT STORAGE AND HANDLING ..... 18-68
18.14.2 EXPLOSIVES STORAGE AND HANDLING ..... 18-68
18.14.3 FUEL STORAGE AND HANDLING ..... 18-69
18.14.4 SITE STORAGE CLOSURE PLAN ..... 18-70
18.15 SITE SERVICES ..... 18-70
18.15.1 PLANT SITE SURFACE WATER MANAGEMENT ..... 18-70
18.15.2 RAW WATER SUPPLY ..... 18-70
18.15.3 PROCESS WATER TANK ..... 18-71
18.15.4 POTABLE WATER TREATMENT ..... 18-71

18.15.5 Assay and Metallurgical Laboratories ..... 18-72
18.15.6 Communications ..... 18-72
18.15.7 Site Security ..... 18-73
18.15.8 Operational Personnel Transport ..... 18-73
18.16 Power Supply and Distribution ..... 18-73
18.16.1 Power Supply ..... 18-73
18.16.2 Power Distribution ..... 18-74
18.16.3 Cables ..... 18-76
18.16.4 Lighting and Small Power ..... 18-76
18.16.5 Vendor Packages ..... 18-76
19.0 MARKET STUDIES AND CONTRACTS ..... 19-1
19.1 Product ..... 19-1
19.2 Markets ..... 19-1
19.3 Refinery Terms ..... 19-2
20.0 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT ..... 20-1
20.1 Introduction ..... 20-1
20.2 Permitting Requirements ..... 20-1
20.2.1 Mining License ..... 20-2
20.2.2 Confirmation of Resources ..... 20-2
20.2.3 Surveys and Studies ..... 20-2
20.2.4 Development and Approval of the Project Design Documentation 20-3
20.2.5 Permitting Process ..... 20-7
20.3 Environmental and Social Studies ..... 20-9
20.3.1 Study Design ..... 20-9
20.3.2 Existing Environmental Conditions ..... 20-13
20.3.3 Existing Socio-economic Conditions ..... 20-21
20.3.4 Stakeholder Agreement ..... 20-24
20.4 Environmental and Social Impact Assessment, Mitigation and Management Plans ..... 20-25
20.4.1 Environmental and Social Impact Assessment ..... 20-25
20.4.2 Environmental and Social Management Plan ..... 20-26
20.5 Water and Waste Management ..... 20-31
20.5.1 Water Management ..... 20-31
20.5.2 Tailings and Waste Management ..... 20-32
20.6 ERM Comments ..... 20-33
20.7 Closure and Reclamation ..... 20-36
21.0 CAPITAL AND OPERATING COST ESTIMATES ..... 21-1
21.1 Capital Costs ..... 21-1
21.1.1 Summary ..... 21-1
21.1.2 Basis of Estimate ..... 21-2
21.1.3 Direct Costs ..... 21-7
21.1.4 Indirect Costs ..... 21-15
21.1.5 Qualifications – Assumptions and Exclusions ..... 21-17
21.2 Operating Cost Estimate ..... 21-19
21.2.1 Summary ..... 21-19
21.2.2 Basis of Operating Cost Estimate ..... 21-19
21.2.3 Open Pit Mining ..... 21-22

21.2.4 UNDERGROUND MINING ..... 21-26
21.2.5 PROCESS ..... 21-27
21.2.6 TAILINGS MANAGEMENT FACILITY ..... 21-31
21.2.7 GENERAL AND ADMINISTRATIVE ..... 21-32

22.0 ECONOMIC ANALYSIS ..... 22-1

22.1 PRE-TAX FINANCIAL ANALYSIS ..... 22-1
22.1.1 MINE/METAL PRODUCTION IN FINANCIAL MODEL ..... 22-1
22.1.2 BASIS OF FINANCIAL EVALUATION ..... 22-2
22.2 SUMMARY OF FINANCIAL RESULTS ..... 22-3
22.3 SENSITIVITY ANALYSES ..... 22-4
22.4 POST-TAX FINANCIAL ANALYSIS ..... 22-6
22.4.1 TAX ASSUMPTIONS ..... 22-6
22.4.2 TAXES AND POST-TAX RESULTS ..... 22-9
22.5 ROYALTIES ..... 22-9
22.6 SMELTER TERMS ..... 22-9
22.7 TRANSPORTATION AND LOGISTICS ..... 22-10
22.8 INSURANCE ..... 22-10

23.0 ADJACENT PROPERTIES ..... 23-1

24.0 OTHER RELEVANT DATA AND INFORMATION ..... 24-1

24.1 PROJECT EXECUTION PLAN ..... 24-1
24.1.1 SCOPE OF WORK ..... 24-1
24.1.2 OBJECTIVES AND EXPECTATIONS ..... 24-2
24.1.3 PROJECT CONSTRAINTS ..... 24-3
24.1.4 ORGANIZATION AND RESPONSIBILITIES ..... 24-5
24.1.5 PROGRAMME ..... 24-8
24.1.6 PROJECT EXECUTION ..... 24-11
24.1.7 PROJECT CONTROLS ..... 24-13
24.1.8 PROCUREMENT ..... 24-15
24.1.9 SITE MANAGEMENT ..... 24-16
24.1.10 PROJECT COMPLETION ..... 24-23
24.2 PROJECT RISKS AND OPPORTUNITIES ..... 24-25
24.2.1 RISKS ..... 24-25
24.2.2 OPPORTUNITIES ..... 24-26
24.3 HYDROGEOLOGY AND WATER SUPPLY ..... 24-27
24.3.1 SITE CHARACTERISTICS ..... 24-27
24.3.2 SCOPE OF SITE INVESTIGATIONS ..... 24-28
24.3.3 FIELD DATA ANALYSIS AND MODELLING ..... 24-31

25.0 INTERPRETATIONS AND CONCLUSIONS ..... 25-1

25.1 GEOLOGY ..... 25-1
25.2 MINERAL RESOURCE ESTIMATE ..... 25-1
25.2.1 VERTIKALNY ..... 25-1
25.2.2 MANGAZEISKY NORTH/SOUTH AND NIZHNY ENDYBAL ..... 25-2
25.3 METALLURGICAL TESTING AND RECOVERIES ..... 25-3
25.4 MINERAL RESERVE ESTIMATES ..... 25-3
25.5 MINING METHODS ..... 25-4
25.5.1 OPEN PIT ..... 25-4
25.5.2 UNDERGROUND MINE ..... 25-4

25.6 PROJECT INFRASTRUCTURE ..... 25-5
25.7 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT ..... 25-6
25.8 HYDROGEOLOGY AND WATER SUPPLY ..... 25-6
25.9 CAPITAL AND OPERATING COST ESTIMATES ..... 25-7
25.9.1 CAPITAL COST ESTIMATE ..... 25-7
25.9.2 OPERATING COST ESTIMATE ..... 25-8
25.10 ECONOMIC ANALYSIS ..... 25-8
25.11 PROJECT EXECUTION PLAN ..... 25-9

26.0 RECOMMENDATIONS ..... 26-1

26.1 GEOLOGY RECOMMENDATIONS ..... 26-1
26.1.1 PHASE 1 – INFILL DRILLING FIRST THREE YEARS OF PRODUCTION ..... 26-1
26.1.2 PHASE 2 – INFILL DRILLING HIGH GRADE MINOR PARALLEL MINERALISED STRUCTURES ..... 26-2
26.1.3 GENERAL GEOLOGY RECOMMENDATIONS ..... 26-3
26.2 MINERAL PROCESSING AND METALLURGICAL TESTING ..... 26-3
26.3 MINING METHODS ..... 26-3
26.4 PROJECT INFRASTRUCTURE ..... 26-4
26.5 TAILINGS MANAGEMENT FACILITY ..... 26-5
26.6 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL OR COMMUNITY IMPACT ..... 26-5
26.7 SITE WATER MANAGEMENT ..... 26-8

27.0 REFERENCES ..... 27-1

27.1 MINERAL PROCESSING AND METALLURGICAL TEST WORK ..... 27-1
27.2 GEOLOGY ..... 27-1
27.3 SITE WATER MANAGEMENT ..... 27-2
27.4 ENVIRONMENTAL ..... 27-2

28.0 CERTIFICATES OF QUALIFIED PERSONS ..... 28-1

28.1 JACQUES DU TOIT, CENG, PRENG, MSCENG, PMP ..... 28-1
28.2 ROBERT DAVIES, BSC (HONS), CGEOL, EURGEOL, FGS ..... 28-3
28.3 SABRY ABDEL HAFEZ, PHD, P.ENG. ..... 28-5
28.4 ARUNASALAM VATHAVOORAN, PHD, CENG, MIMMM ..... 28-6
28.5 ANTON FERDINAND VON WIELLIGH, B.ENG., PR.ENG., MSAIMM ..... 28-8
28.6 MAX BROWN, BSC, MSC, CENG, MIMMM ..... 28-10
28.7 RENE GHARAPETIAN, P.ENG. ..... 28-11
28.8 SAUNJAY DUGGAL, MSC, P.ENG. ..... 28-12
28.9 LASZLO BODI, MSC, CENG, P.ENG ..... 28-13
28.10 KRYSZTOF CZAJEWSKI, BSC, P.ENG ..... 28-15
28.11 DAMIAN HICKS, MIEAUST, CPENG ..... 28-16
28.12 DEREK CHRISTOPHER CHUBB, P.ENG. ..... 28-17
28.13 GUY ROEMER, PE ..... 28-19
28.14 HOUCYNE EL IDRYSY, PHD, CGEOL, FGS ..... 28-20

# APPENDICES

APPENDICES ARE AVAILABLE AT THE OFFICES OF SILVER BEAR RESOURCES INC.

APPENDIX A METALLURGICAL TEST WORK REPORTS
APPENDIX B MINE GEOTECHNICAL REPORT
APPENDIX C OPEN PIT AND UNDERGROUND MINING REPORT
APPENDIX D PROCESS FLOW DIAGRAMS
APPENDIX E SITE LAYOUT AND GENERAL ARRANGEMENT DRAWINGS
APPENDIX F PIPING AND INSTRUMENTATION DIAGRAMS
APPENDIX G ELECTRICAL DRAWINGS
APPENDIX H EQUIPMENT LIST AND LOAD LIST
APPENDIX I CIVIL GEOTECHNICAL REPORT
APPENDIX J TAILINGS MANAGEMENT REPORT
APPENDIX K HYDROGEOLOGY REPORT
APPENDIX L CAPITAL COST ESTIMATE
APPENDIX M OPERATING COST ESTIMATE
APPENDIX N FINANCIAL ANALYSIS

# LIST OF TABLES

Table 1.1 Mangazeisky Project Summary ..... 1-1
Table 1.2 Consulting Company Responsibilities ..... 1-2
Table 1.3 Mining License Coordinates ..... 1-4
Table 1.4 Exploration License Coordinates ..... 1-4
Table 1.5 Property Mineral Licences ..... 1-4
Table 1.6 Historic Exploration Activities at the Property ..... 1-8
Table 1.7 Summary of Drilling on the Property ..... 1-9
Table 1.8 Total Resources for the Mangazeisky Property ..... 1-11
Table 1.9 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016 ..... 1-13
Table 1.10 Capital Cost Summary ..... 1-21
Table 1.11 LOM Averaged Operating Cost Summary ..... 1-22
Table 1.12 Critical Risks ..... 1-23
Table 1.13 Project Recommendations ..... 1-25
Table 2.1 Consulting Company Responsibilities ..... 2-1
Table 2.2 Summary of QPs ..... 2-2

Table 4.1 Mining License Coordinates ..... 4-3
Table 4.2 Exploration License Coordinates ..... 4-3
Table 4.3 Property Mineral Licences ..... 4-4
Table 6.1 Summary of the Historical Russian Inventory by Mineralised Zone for the Property ..... 6-5
Table 6.2 Summary of the Historical Russian P1 and P2 Inventory for the Property ..... 6-6
Table 6.3 Historical Resources for the Property ..... 6-6
Table 9.1 Historic Exploration Activities at the Property ..... 9-1
Table 9.2 Summary of Intersections from 2011 to 2012 Trenches at Nizhny Endybal with a Silver Grade of >75 g/t ..... 9-2
Table 9.3 Summary of Intersections from 2013 Trenches on Mangazeisky North; with a Silver Grade of >75 g/t Ag ..... 9-4
Table 9.4 Summary of Significant Intersections from 2014 Trenching Campaigns; Silver Grade of >100 g/t or Gold Grade >0.5 g/t ..... 9-5
Table 10.1 Summary of Drilling on the Property ..... 10-1
Table 10.2 Summary of 2015 Drillholes ..... 10-3
Table 10.3 2013/2014 Drill Programme Significant Intersections; >1 m at >100 g/t Silver ..... 10-4
Table 10.4 Mineralisation Thickness Observed in 2013 Drilling ..... 10-4
Table 11.1 SRMs used in the Vertikalny Exploration ..... 11-6
Table 11.2 SRMs used in the Nizhny Endybal Exploration during 2011 and 2012 ..... 11-13
Table 11.3 Silver Standard Performance ..... 11-15
Table 12.1 Verified Drillhole Collar Coordinates (UTM WGS 84) ..... 12-2
Table 13.1 2008 Sample Chemical Analysis ..... 13-2
Table 13.2 Silver Association ..... 13-2
Table 13.3 Gravity and Flotation Test Work Overview ..... 13-3
Table 13.4 Sample Chemical Composition ..... 13-5
Table 13.5 SB-2 Silver Association ..... 13-5
Table 13.6 SB-1 Flotation Test Work Results at 96.5% -71 µm ..... 13-6
Table 13.7 SB-2 Locked Cycle Flotation Test Results ..... 13-6
Table 13.8 SB-2 Locked Cycle Flotation Test Results ..... 13-7
Table 13.9 Samples Sent to SGS Vostok ..... 13-9
Table 13.10 Specific Gravity of the Ore ..... 13-12
Table 13.11 Summary of Head Assays ..... 13-12
Table 13.12 Summary of Whole Rock Analysis ..... 13-12
Table 13.13 Summary of Diagnostic Leach Results ..... 13-16
Table 13.14 Summary of Comminution Results ..... 13-17
Table 13.15 Effect of Grind on Gravity Concentration ..... 13-18
Table 13.16 Summary of GRS test results ..... 13-19
Table 13.17 Bulk Gravity Concentration Results ..... 13-20
Table 13.18 Test Condition for Intensive Cyanidation ..... 13-20
Table 13.19 Silver Recovery to Solution by Intensive Cyanidation ..... 13-20
Table 13.20 Overall Silver Recovery Calculation for Gravity Based Flowsheet ..... 13-27
Table 13.21 Effect of Grind Flotation Test Results ..... 13-28
Table 13.22 Summary of Locked Cycle Test Results (Selective Flotation) ..... 13-28
Table 13.23 Summary of Bulk Flotation Results ..... 13-29
Table 13.24 Silver Recovery to Solution by Intensive Cyanidation ..... 13-29
Table 13.25 Overall Silver Recovery of Flotation Based Option ..... 13-30
Table 13.26 Summary of Heap Leach Predictor Results ..... 13-31
Table 13.27 ROM Leach Test Conditions ..... 13-32
Table 13.28 Test Conditions for Reference Leach Test ..... 13-33
Table 13.29 Test Conditions for ROM Leach Optimisation Tests ..... 13-35
Table 13.30 Summary of the Results from Direct Electrowinning Test Work ..... 13-37
Table 13.31 Silver Product Quality Analysis (%) ..... 13-39
Table 13.32 Thickening test results ..... 13-39
Table 13.33 Filtration Tests Results ..... 13-40

Table 13.34 Summary of Cyanide destruction test results ..... 13-40
Table 13.35 ABA Results ..... 13-41
Table 13.36 Tetra Tech Sample Recommendations for Leach Variability Test Work ..... 13-41
Table 13.37 Silver Head Assays ..... 13-42
Table 13.38 Leach Test Conditions ..... 13-43
Table 13.39 Leach Results for Oxidized Samples ..... 13-44
Table 13.40 Leach Results for Transition Samples ..... 13-44
Table 13.41 Leach Results for Primary Samples ..... 13-44
Table 13.42 Sample List for Primary Ore Composite ..... 13-45
Table 13.43 Head Assays of the Primary Ore Composite ..... 13-47
Table 13.44 Whole Rock Analysis of the Primary Ore Composite ..... 13-47
Table 13.45 Mineralogical Analysis ..... 13-48
Table 13.46 Bond Ball Mill Index Test Results ..... 13-48
Table 13.47 Baseline Leach Test Conditions ..... 13-49
Table 13.48 Baseline Leach Test Results ..... 13-50
Table 13.49 Grind Size Optimization Results ..... 13-50
Table 13.50 Cyanide Concentration Optimization Results ..... 13-50
Table 13.51 Leach Test Condition for Optimized Condition Test ..... 13-51
Table 13.52 Results of the Leach under Optimized Conditions ..... 13-51
Table 13.53 Summary of MLR Analysis ..... 13-54
Table 13.54 MLR Parameters ..... 13-54
Table 13.55 Effect of Grind Results ..... 13-56
Table 13.56 Bulk Flotation Results ..... 13-57
Table 13.57 Test Conditions for Intensive Cyanidation Tests ..... 13-57
Table 13.58 Intensive Cyanidation Results ..... 13-58
Table 13.59 Pro-rating of Variability Leach Results for Plant Design Conditions ..... 13-60
Table 13.60 Overall Recovery Calculation for Oxides ..... 13-60
Table 14.1 Raw Drillhole Statistics ..... 14-7
Table 14.2 Summary of Mineralisation Domains ..... 14-8
Table 14.3 Descriptive Statistics for Selected Raw Samples ..... 14-9
Table 14.4 Table Statistics of Selected Raw Samples and 0.7 m Composites ..... 14-14
Table 14.5 Mean Density Values per Lithology Group ..... 14-17
Table 14.6 Directional Variogram Parameters ..... 14-19
Table 14.7 Vertikalny Central Block Model Parameters ..... 14-19
Table 14.8 Vertikalny Northwest Block Model Parameters ..... 14-19
Table 14.9 Comparison of Block Model and Wireframe Volume ..... 14-20
Table 14.10 Estimation Parameters ..... 14-21
Table 14.11 Statistics Comparing Block Estimate and Composite Grades ..... 14-23
Table 14.12 Summary of Mineral Resources – Vertikalny Deposit ..... 14-29
Table 14.13 Vertikalny Central Indicated Blocks – Grade-Tonnage Sensitivity ..... 14-30
Table 14.14 Vertikalny Central Inferred Blocks – Grade-Tonnage Sensitivity ..... 14-30
Table 14.15 Vertikalny North West Inferred Blocks - Grade Tonnage Sensitivity ..... 14-30
Table 14.16 Total Resources for the Mangazeisky Property ..... 14-32
Table 15.1 Open Pit Cut-off Grade Calculation Parameters ..... 15-1
Table 15.2 Underground Cut-off Grade Calculation Parameters ..... 15-1
Table 15.3 Break-even Mining Cut-off Grade Calculations ..... 15-3
Table 15.4 Marginal Mining Cut-off Grade Calculations ..... 15-3
Table 15.5 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016 ..... 15-4
Table 16.1 Recommended Slope Angles ..... 16-2
Table 16.2 Optimisation Parameters ..... 16-3
Table 16.3 Pit Design Parameters ..... 16-8
Table 16.4 In Situ Rock Inventories in the Designed Pit Phases (September 2016) ..... 16-12
Table 16.5 Open Pit Mining Operating, Stockpile Inventory, and Plant Production Schedul ..... 16-16
Table 16.6 Scheduled Benches per Mining Periods ..... 16-19
Table 16.7 Required Equipment Summary ..... 16-23

Table 16.8 Summary of the Existing Mining Equipment On Site ..... 16-24
Table 16.9 Ventilation Flow Requirements ..... 16-37
Table 16.10 Water Usage Calculations ..... 16-38
Table 16.11 Development Summary ..... 16-43
Table 16.12 Equipment Units Simulated ..... 16-47
Table 17.1 Process Design Criteria ..... 17-2
Table 17.2 Primary Equipment List ..... 17-8
Table 18.1 Winter Road Transportation Tonnages ..... 18-6
Table 18.2 Winter Road Transportation Load Tonnages 2015/2016 by Item ..... 18-7
Table 18.3 Annual Winter Road Transportation Tonnages by Item ..... 18-7
Table 18.4 Recent Geotechnical Investigation Field Notes, Presenting the Intercepted Layers at Three Representative Test Locations at the Camp Site ..... 18-14
Table 18.5 Recent Geotechnical Investigation Field Notes, Presenting the Intercepted Layers at Representative Test Locations at the Proposed Dry Stack TMF Site ..... 18-18
Table 18.6 Vertical D/L ..... 18-24
Table 18.7 Lateral D/H ..... 18-25
Table 18.8 Member Depths (d/L) ..... 18-25
Table 18.9 Minimum Slab on Grade ..... 18-25
Table 18.10 Minimum Live Loads ..... 18-26
Table 18.11 Structural Steel Eurocodes ..... 18-26
Table 18.12 Concrete Specified Compressive Strength ..... 18-27
Table 18.13 Reinforcing Steel ..... 18-27
Table 18.14 Processing and Infrastructure Mobile Fleet ..... 18-37
Table 18.15 Equipment Packages ..... 18-44
Table 18.16 Average Monthly Temperature Statistics (°C) for the Syuryen-Kyuyel Meteorological Station ..... 18-60
Table 18.17 Percent Mean Annual Flow during each Month, Dulgalakh River at Syuryen-Kyuyel ..... 18-61
Table 18.18 Average and Select Percentiles of the Cumulative Annual Groundwater Demand ..... 18-67
Table 18.19 Reagent Usage ..... 18-68
Table 18.20 Maximum Yearly Fuel Consumption ..... 18-69
Table 18.21 Pump Station Power Requirements ..... 18-71
Table 18.22 Estimated Load Summary ..... 18-74
Table 18.23 Estimated Remote Site Loads ..... 18-74
Table 19.1 Refinery Terms ..... 19-2
Table 20.1 Mangazeisky Project Design Documentation Development and Approval Process ..... 20-4
Table 20.2 Required Permits ..... 20-7
Table 20.3 Environmental and Social Studies Completed (as of June 2016) ..... 20-10
Table 20.4 Summary of Terrestrial Ecosystem Communities ..... 20-18
Table 20.5 Key Project Stakeholder Groups ..... 20-24
Table 20.6 Environmental and Social Potential Impacts and Proposed Embedded Design Mitigation ..... 20-27
Table 21.1 Capital Cost Summary ..... 21-1
Table 21.2 Estimate Responsibility Matrix ..... 21-3
Table 21.3 Construction and Installation Teams ..... 21-5
Table 21.4 Foreign Exchange Rates ..... 21-6
Table 21.5 Initial Open Pit Capital Costs ..... 21-8
Table 21.6 Underground Mining Capital Costs ..... 21-8
Table 21.7 Key Quantities ..... 21-9
Table 21.8 Mechanical Equipment Procurement Packages ..... 21-9
Table 21.9 Processing Capital Cost Estimate ..... 21-10
Table 21.10 Infrastructure Capital Cost Estimate ..... 21-11
Table 21.11 Site Facilities Capital Cost Estimate ..... 21-12
Table 21.12 Utilities Capital Cost Estimate ..... 21-13

Table 21.13 TMF Capital and Sustaining Capital Expenditure Summary ..... 21-14
Table 21.14 Indirect Capital Cost Estimate ..... 21-15
Table 21.15 Initial Capital EPCM Cost Estimate ..... 21-16
Table 21.16 Owner's Cost Capital Cost Estimate ..... 21-16
Table 21.17 Allowances ..... 21-17
Table 21.18 LOM Averaged Operating Cost Summary ..... 21-19
Table 21.19 Power Generation Cost Estimate ..... 21-20
Table 21.20 Personnel Roles ..... 21-21
Table 21.21 Open Pit Labour ..... 21-22
Table 21.22 Open Pit Blasting Parameters ..... 21-23
Table 21.23 Drilling and Blasting Costs ..... 21-23
Table 21.24 Truck Cycle Times and Fuel Usage Parameters ..... 21-24
Table 21.25 Fuel Consumption and Maintenance Costs ..... 21-25
Table 21.26 Monthly Leasing Costs ..... 21-25
Table 21.27 Average Open Pit Mining Unit Operating Costs ..... 21-26
Table 21.28 Underground Mining Operating Costs ..... 21-26
Table 21.29 Process Plant Unit Operating Cost Summary ..... 21-28
Table 21.30 Plant Labour Cost Estimate ..... 21-29
Table 21.31 Reagent and Consumables Cost Estimate ..... 21-30
Table 21.32 Maintenance and Spares Cost Estimate ..... 21-30
Table 21.33 Power Cost Estimate ..... 21-31
Table 21.34 TMF Operating Expenditure Summary ..... 21-31
Table 21.35 Average LOM G&A Operating Costs ..... 21-32
Table 21.36 Average G&A Expense Breakdown ..... 21-33
Table 21.37 Corporate Expenses ..... 21-34
Table 21.38 Camp Expenses ..... 21-34
Table 21.39 G&A Labour Costs ..... 21-35
Table 22.1 Mine/Metal Production from the Mangazeisky Silver Project ..... 22-2
Table 22.2 Summary of Pre-tax Financial Results ..... 22-3
Table 22.3 Taxes and Post-tax Results ..... 22-9
Table 24.1 Key Performance Indicators ..... 24-3
Table 24.2 Language Utilisation ..... 24-5
Table 24.3 Roles and Responsibilities ..... 24-8
Table 24.4 Project Interfaces ..... 24-12
Table 24.5 Critical Risks ..... 24-25
Table 24.6 Average Monthly and Annual Precipitation (mm) ..... 24-27
Table 24.7 Measured Artesian Outflow Rates in Borehole GS15-05 ..... 24-31
Table 24.8 Average Annual Discharges or Surveyed River Sections ..... 24-33
Table 24.9 Estimated Storm Depths for Mangaziesky Site ..... 24-33
Table 24.10 Estimated Peak Flow from Storm Events for Five Defined Return Periods ..... 24-34
Table 24.11 Borehole Coordinates and Depth of Permafrost ..... 24-35
Table 24.12 Measured and Inferred Groundwater Levels in the Boreholes ..... 24-38
Table 24.13 Borehole Groundwater Quality Data ..... 24-39
Table 24.14 Comparison of Water Supply Potential of the Boreholes ..... 24-41
Table 24.15 Hydraulic Properties used for the Numerical Model Layer 2 (Sub-permafrost Aquifer) ..... 24-43
Table 25.1 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016 ..... 25-4
Table 25.2 Capital Cost Summary ..... 25-7
Table 25.3 LOM Averaged Operating Cost Summary ..... 25-8

# LIST OF FIGURES

Figure 1.1 Property Location Map ..... 1-3
Figure 1.2 Regional Geology Map ..... 1-6
Figure 1.3 Conceptual Process Block Flow Diagram ..... 1-16
Figure 1.4 Site Infrastructure Layout ..... 1-18
Figure 1.5 Process Plant Facility Layout ..... 1-19
Figure 4.1 Property Location Map ..... 4-2
Figure 5.1 Airports and Current Haul Route ..... 5-3
Figure 6.1 Historical Trenches on the Property; Porphyrovy Zone ..... 6-2
Figure 7.1 Regional Geology of the Property ..... 7-2
Figure 7.2 Silver Projects within the Sakha Republic of Yakutia ..... 7-4
Figure 7.3 Exploration Targets and Property Geology ..... 7-5
Figure 7.4 West to East Cross Section through Mangazeisky North ..... 7-6
Figure 7.5 Mineral Zonation of the Vertikalny Structure ..... 7-8
Figure 7.6 Beginning of the Mineralised Intersection from Drillhole V13-020 ..... 7-9
Figure 7.7 Stratiform Siderite Veining in Drillhole END-31A ..... 7-12
Figure 7.8 Vertical Cross-Section through Drillholes END-16, END-18, END-26, END-28A and END-29 Looking North ..... 7-13
Figure 7.9 Representation of the Geometry of the Interpreted Structural Features ..... 7-14
Figure 7.10 General View of Nizhny Endybal ..... 7-15
Figure 7.11 Siderite Vein with Vugs filled with Fahlore Crystals, Galena, Ankerite and Quartz ..... 7-15
Figure 7.12 Siderite Vein with Tetrahedrite Crystal ..... 7-16
Figure 7.13 Magnetic Anomaly Map ..... 7-17
Figure 8.1 Idealised Section through a Porphyry and Epithermal Deposit Model ..... 8-1
Figure 9.1 Plan Illustrating 2013 Trench Locations on Mangazeisky North Zone ..... 9-3
Figure 9.2 Example of Trench Mapping and Sample Profiling from K13-21 ..... 9-7
Figure 9.3 Sampling Profiles within Trench K13-21 ..... 9-7
Figure 10.1 Drilling at Vertikalny in 2011 ..... 10-5
Figure 10.2 Drilling at Vertikalny in November 2013 ..... 10-6
Figure 10.3 Example of Core Tray Markings ..... 10-8
Figure 10.4 Core Logging ..... 10-10
Figure 10.5 Core Photography ..... 10-11
Figure 10.6 Example of How to Set up a Photograph of the Core Box ..... 10-12
Figure 10.7 Geological Logging of Core Samples ..... 10-13
Figure 10.8 Silver Grade vs. Sampled Length ..... 10-15
Figure 10.9 Drillhole Collar Locations and Mineralisation ..... 10-15
Figure 10.10 Section through the Central Zone of Vertikalny ..... 10-16
Figure 11.1 Crushing Equipment in Silver Bear's On-site Sample Preparation Facilities ..... 11-1
Figure 11.2 Sample Splitting in Silver Bear's On-site Sample Preparation Facilities ..... 11-2
Figure 11.3 Coarse Reject Store Shed ..... 11-3
Figure 11.4 Weighing Scales in Silver Bear's On-site Sample Preparation Facilities ..... 11-3
Figure 11.5 Blanks Chart for Vertikalny Exploration Data ..... 11-5
Figure 11.6 GBM913-13 Chart for Vertikalny Exploration Data ..... 11-7
Figure 11.7 GBM997-4 Chart for Vertikalny Exploration Data ..... 11-7
Figure 11.8 GBM906-6 Chart for Vertikalny Exploration Data ..... 11-8
Figure 11.9 GBM998-9 Chart for Vertikalny Exploration Data ..... 11-8
Figure 11.10 GBM303-1 Chart for Vertikalny Exploration Data ..... 11-9
Figure 11.11 GBM310-16 Chart for Vertikalny Exploration Data ..... 11-10
Figure 11.12 GBM909-13 Chart for Vertikalny Exploration Data ..... 11-10
Figure 11.13 GBM909-11 Chart for Vertikalny Exploration Data ..... 11-11
Figure 11.14 Duplicate Chart for Vertikalny Exploration Data ..... 11-12
Figure 11.15 Nizhny Endybal Duplicate Chart ..... 11-14

Figure 11.16 Blank Sample Performance ..... 11-15
Figure 11.17 Standard GBM906-6 Performance ..... 11-16
Figure 11.18 Standard GBM909-13 Performance ..... 11-16
Figure 11.19 Standard GBM310-16 Performance ..... 11-17
Figure 11.20 Pulp Duplicate Performance (Log Scale) ..... 11-17
Figure 12.1 Grab Sample from Trench K-1322 at Mangazeisky North ..... 12-3
Figure 12.2 Core Logging Facilities; Indoor and Outdoor ..... 12-4
Figure 12.3 Sample Preparation Equipment; (left to right) Pneumatic Splitter, Sample Dryer (Kiln), Samples Being Crushed and Jaw Crusher ..... 12-6
Figure 12.4 Core Storage Facilities; Current and New Core Storage Facilities ..... 12-7
Figure 12.5 Sample Pulps Storage ..... 12-7
Figure 12.6 Mineralised Veins in Outcrop at Verticalny Central (Left) and Mangazeisky North (Right) ..... 12-8
Figure 13.1 Location of Metallurgical Drillholes ..... 13-8
Figure 13.2 Mineralised Zones within the Orebody ..... 13-9
Figure 13.3 Sample Delivered to SGS Vostok ..... 13-10
Figure 13.4 One of the Delivered Core Boxes at SGS Vostok ..... 13-10
Figure 13.5 Sample Preparation Flowsheet ..... 13-11
Figure 13.6 Summary of Modal Mineralogy ..... 13-14
Figure 13.7 Liberation and Association of Silver Minerals ..... 13-15
Figure 13.8 Exposure of Silver Minerals ..... 13-15
Figure 13.9 Knelson KC-MD3 Laboratory Batch Test Unit ..... 13-18
Figure 13.10 Effect of Grind Leach Test Results ..... 13-21
Figure 13.11 Effect of Cyanide Addition Leach Results ..... 13-22
Figure 13.12 Effect of Pulp Density Results ..... 13-23
Figure 13.13 Effect of Silver Nitrate Addition ..... 13-24
Figure 13.14 Effect of Time Test/Leach Kinetics ..... 13-24
Figure 13.15 Leach Kinetics for Re-leaching the Leach Tails ..... 13-26
Figure 13.16 Conceptual Block Flow Diagram for Gravity and Leach Based Option ..... 13-26
Figure 13.17 Laboratory Flotation Cell ..... 13-27
Figure 13.18 Conceptual Block Flow Diagram for Flotation Option ..... 13-30
Figure 13.19 Heap Leach Test Results ..... 13-31
Figure 13.20 Leach Kinetics of the Preliminary ROM Leach Test ..... 13-32
Figure 13.21 Bottle Roll Cyanide Leach Test Sample Preparation ..... 13-33
Figure 13.22 Reference Leach Test Results ..... 13-34
Figure 13.23 Leach Kinetic Curves for the Optimisation Tests ..... 13-35
Figure 13.24 Direct Electrowinning Test in Progress at SGS Vostok ..... 13-36
Figure 13.25 Depletion Curves for Silver, Copper and Zinc ..... 13-37
Figure 13.26 Silver Powder Collected from Cathode ..... 13-38
Figure 13.27 Silver Button Produced by Melting the Deposited Silver ..... 13-38
Figure 13.28 Agitated Leach Test in Progress ..... 13-43
Figure 13.29 Sample Preparation Flowsheet ..... 13-46
Figure 13.30 Agitated Tank Leach Tests ..... 13-49
Figure 13.31 Leach Kinetics Curves ..... 13-52
Figure 13.32 Variation of Leach Dissolution with Grind Size ..... 13-53
Figure 13.33 Variation of Leach Dissolution with Cyanide Concentration ..... 13-53
Figure 13.34 Validation of MLR Constants ..... 13-55
Figure 13.35 Laboratory Flotation Test ..... 13-55
Figure 13.36 Summary of Effect of Grind Test Results ..... 13-56
Figure 14.1 Mineralised Domains at Vertikalny Central ..... 14-4
Figure 14.2 Plan and Cross Section through Vertikalny Central Wireframe Models ..... 14-5
Figure 14.3 Plan and Cross Section through Vertikalny Northwest Wireframe Models ..... 14-6
Figure 14.4 Log Histogram of all Raw Samples ..... 14-8
Figure 14.5 Box and Whisker Plot of Selected Raw Samples ..... 14-9
Figure 14.6 Log Histogram of Selected Raw Samples from Domain V1 ..... 14-10
Figure 14.7 Log Histogram of Selected Raw Samples from Domain H1 ..... 14-10

Figure 14.8 Log Histogram of Selected Raw Samples from Domains V2-V10 ..... 14-11
Figure 14.9 Log Histogram of Selected Raw Samples from Domains VNW ..... 14-11
Figure 14.10 Length Histogram for Selected Raw Samples with V1 Domain ..... 14-12
Figure 14.11 Sample Length Plotted Against Silver Grade ..... 14-12
Figure 14.12 Log Histogram of Silver Grades from Selected Raw Samples and 0.7 m Composites for Vertikalny Central Domains ..... 14-13
Figure 14.13 Log Histogram for Domain V1 Illustrating Capping Level ..... 14-15
Figure 14.14 Log Probability Plot for Vertikalny Central Domains ..... 14-16
Figure 14.15 Log Probability Plot for VNW Domain ..... 14-16
Figure 14.16 3D Isometric View Illustrating the Theoretical Interaction between the Mineralised Vein and the Oblique Structure ..... 14-18
Figure 14.17 Semi Variogram and Associated Variogram Map for V1 North – Major Direction 14-18
Figure 14.18 Long Section Showing Composites and Estimated Block Grades for Vertikalny Central ..... 14-21
Figure 14.19 Long Section Showing Composites and Estimated Block Grades for Vertikalny Northwest ..... 14-22
Figure 14.20 Northing Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Central ..... 14-24
Figure 14.21 Easting Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Central ..... 14-25
Figure 14.22 Northing Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Northwest ..... 14-25
Figure 14.23 Long Section of the Mineral Resource Classification for Vertikalny Central .. 14-27
Figure 14.24 Long Section of the Mineral Resource Classification and Slope of Regression ..... 14-27
Figure 14.25 Grade-Tonnage Curve for Indicated & Inferred Resources at Vertikalny Central Zone ..... 14-34
Figure 14.26 Grade-Tonnage Curve for Inferred Resource at Vertikalny Northwest Zone .. 14-34
Figure 16.1 Optimisation Summary for the Base Case ..... 16-4
Figure 16.2 Optimisation Summary for the Scenario using Shallower Slope Angle ..... 16-4
Figure 16.3 Plan View of the Selected Pit Shell Contours ..... 16-5
Figure 16.4 Summary of Sensitivity Analyses on Pit Value ..... 16-6
Figure 16.5 Grade-Tonnage Curve for North Pit ..... 16-7
Figure 16.6 Grade-Tonnage Curve for South Pit ..... 16-7
Figure 16.7 Plan View of the Phase 1 Pit (North Pit) ..... 16-10
Figure 16.8 Plan View of the Final Pit (North Pit) ..... 16-11
Figure 16.9 Plan View of the Final Pit (South Pit) ..... 16-12
Figure 16.10 General Layout of the Design Pits, Waste Dump and Haul Roads ..... 16-13
Figure 16.11 Open Pit Mining Schedule and Plant Head Grade from the Open Pit ..... 16-18
Figure 16.12 Approximate End of 2016 Pit Plan ..... 16-20
Figure 16.13 Approximate End of 2017 Pit Plan ..... 16-21
Figure 16.14 General Underground Mine Design Layout ..... 16-30
Figure 16.15 South Zone Top-level Access ..... 16-31
Figure 16.16 Stope Grade Profile (Planned Stopes) ..... 16-34
Figure 16.17 Stope ROM Production Profile (Schedule) ..... 16-35
Figure 16.18 Underground Mine Development Schedule ..... 16-36
Figure 16.19 Development Sizes ..... 16-40
Figure 16.20 Other Excavation Sizes ..... 16-40
Figure 16.21 Single Boom Jumbo Drill Rig for Development Drilling ..... 16-41
Figure 16.22 Typical LHD Equipment Size Specification Considered ..... 16-41
Figure 16.23 20-t Underground Mining Truck Dimensions Considered ..... 16-42
Figure 16.24 Long Hole Drill Rig (Typical Dimensions) ..... 16-42
Figure 16.25 Monthly Development Meters Scheduled ..... 16-44
Figure 16.26 Stope ROM Schedule ..... 16-45
Figure 16.27 Total ROM Production (Monthly) ..... 16-45

Figure 16.28 Silver Profile (Monthly) ... 16-46
Figure 16.29 Combined Open Pit and Underground Schedule (Monthly) ... 16-46
Figure 16.30 Mechanised Sub-level Open Stoping ... 16-48
Figure 17.1 Block Flow Diagram of the Proposed Process Plant ... 17-10
Figure 17.2 3D Model of an emew® Cell Technology ... 17-14
Figure 17.3 Silver Powder Deposition on Cathode Surface ... 17-15
Figure 18.1 Transport Routes ... 18-4
Figure 18.2 Winter Road ... 18-5
Figure 18.3 Estimated Truck Loads to Site 2016/2017 ... 18-8
Figure 18.4 Site Infrastructure Layout ... 18-10
Figure 18.5 Process Plant Facility Layout ... 18-11
Figure 18.6 General Plan Showing the Mine Site Area, Airstrip, and Area River Valleys ... 18-12
Figure 18.7 Surface Soil Conditions across the Airstrip and along the Road to the Mine Site ... 18-13
Figure 18.8 Bank of the Sirelendge River Next to the Airstrip ... 18-13
Figure 18.9 Representative Geotechnical Test Locations across the New Camp Site and Storage Areas ... 18-14
Figure 18.10 Soil Conditions across the Storage Areas ... 18-16
Figure 18.11 Borehole Locations in the Area of the TMF ... 18-17
Figure 18.12 Soil (Weathered Rock Fragments) Conditions across the Plant Site ... 18-19
Figure 18.13 General Soil Conditions (Shallow Weathered Rock) Across the Upper Plateau, Approximately 400 m above the Adjacent Sirelendge Valley ... 18-20
Figure 18.14 Ground Temperature Profile and Extent of Active Layer in Permafrost Areas 18-22
Figure 18.15 Peak Ground Acceleration Map of Northern Eurasia – 5% Probability of Exceedance in 50 years ... 18-29
Figure 18.16 Gravel, Cobbles, and Boulders on the Valley Floor of the Sirelendge River ... 18-31
Figure 18.17 River Crossing Upgrade with Culverts ... 18-32
Figure 18.18 Condition of the Existing Road in the Side Valley, Where Weathered Rock and Granular Fill with Various Thicknesses Cover the Valley Floor ... 18-33
Figure 18.19 KRAZ 65032 Specifications ... 18-33
Figure 18.20 Width of Mine Roads ... 18-34
Figure 18.21 Cross Section of Mine Roads, with Side Ditch and Safety Berm ... 18-34
Figure 18.22 Representative Soil Conditions in the Narrow Borisovsky Valley ... 18-36
Figure 18.23 All-terrain Vehicles, Planned for Operation at the Mine Site ... 18-37
Figure 18.24 Process Plant Layout ... 18-42
Figure 18.25 Electrowinning Concept Drawing ... 18-43
Figure 18.26 General Soil Conditions at the Floor of the Borisovsky Valley (Cobbles and Boulders with Some Silt and Clay Filling in the Voids) ... 18-55
Figure 18.27 Relationship between pH, AP and NP in Representative Waste Rock and Tailings Samples (based on tests results provided by the Geoelectrochemistry Lab) 18-56
Figure 18.28 Staged Deposition of Waste Rock, Starting at the 1,070 m Elevation Level. 18-57
Figure 18.29 Variation in Internal Friction Angle within a Rockfill Mass ... 18-58
Figure 18.30 Representative Slope Inclinations and Slope Ratios (V:H) ... 18-58
Figure 18.31 Average Monthly Temperature Distributions ... 18-60
Figure 18.32 Comparison of the Mean Annual Sirelendge River Discharge Distribution used in the WBM and Select Percentile Values from OOO ISKOM (2015) ... 18-61
Figure 18.33 Human-use Water Demand Distributions used in the WBM ... 18-62
Figure 18.34 Average Monthly Groundwater Demands Predicted for Human Use, Ore Processing, Underground Mining, and the Cumulative Groundwater Demand from these Sources ... 18-66
Figure 18.35 Median and Percentile Ranges for the Predicted Monthly Total Groundwater Demand Time-series ... 18-67
Figure 18.36 Suggested Cross Section of the Runoff Water Collection Ditch ... 18-70
Figure 18.37 Earthing System ... 18-75
Figure 20.1 Surface Water Quality Compared to MPC for Water Courses for Fishery Water Bodies (MPCf) ... 20-14

Figure 20.2 Alpine-type Terrain of the Area along the Axis of the Verkhoyansk Range ..... 20-15
Figure 20.3 Stone-runs of Small Boulders in Near-the-edge Area of the Right Bank of the Borisovsky Creek Valley ..... 20-16
Figure 20.4 Micro Landslides on Taluses, Left Bank of the Sirilendie River Valley, Opposite the Workers' Settlement, after a Heavy Rain on 8th August 2015 ..... 20-16
Figure 20.5 Small Mudflow Channel after a Heavy Rain on 8th August 2015 in the Cleavage of the Northern Slope of Mount Endybal ..... 20-17
Figure 20.6 SPNAs in the Surroundings of the Project Area ..... 20-21
Figure 20.7 Location of License (Project) area in Kobyaysky District ..... 20-22
Figure 21.1 Cost Percentages per Discipline ..... 21-2
Figure 21.2 Average Open Pit Mining Unit Operating Costs ..... 21-26
Figure 21.3 Underground Mining Operating Costs ..... 21-27
Figure 22.1 Pre-tax Undiscounted Annual and Cumulative Net Cash Flows ..... 22-3
Figure 22.2 Pre-tax NPV Sensitivity Analysis ..... 22-5
Figure 22.3 Pre-tax IRR Sensitivity Analysis ..... 22-5
Figure 22.4 Pre-tax Payback Period Sensitivity Analysis ..... 22-6
Figure 24.1 Project Organizational Structure ..... 24-7
Figure 24.2 Mangazeisky Project Schedule ..... 24-10
Figure 24.3 3D View of the Project Area Topography and Hydrography, Showing Borehole Locations ..... 24-30
Figure 24.4 Local Hydrological Catchments and Location of Flow Monitoring Points ..... 24-32
Figure 24.5 Regional Drainage Catchment ..... 24-32
Figure 24.6 Temperature Profiles in Borehole T006 ..... 24-35
Figure 24.7 Geothermal Gradient and Interpolation of the Permafrost Bottom Depth in Borehole VG-2 ..... 24-36
Figure 24.8 Cross-section along Boreholes G-1 and VG-2 Showing Position of the Permafrost Bottom in Respect to the Underground Mine (Black) ..... 24-37
Figure 24.9 Groundwater Level Spatial Distribution (Contour Levels in mamsl) ..... 24-38
Figure 24.10 Extent and Structure of the Groundwater Model (white lines are faults) ..... 24-42
Figure 24.11 Predicted Water Level in the Water Supply Well – Scenario 1 ..... 24-44
Figure 24.12 Predicted Water Level in the Water Supply Well – Scenario 2 ..... 24-45
Figure 24.13 Predicted Cone of Depression Due to Pumping – Scenario 2 (m) ..... 24-45
Figure 24.14 Predicted Water Level in the Water Supply Well – Scenario 3 ..... 24-46
Figure 26.1 Proposed Drillhole Pierce Points ..... 26-1
Figure 26.2 3D Isometric View of the Mineralised Intercepts and Mineralisation Wireframe in the Southern Part of the Vertikalny Area ..... 26-2

# GLOSSARY

## *Units of Measure*

| | |
|---|---|
| above mean sea level | amsl |
| acre | ac |
| ampere | A |
| annum (year) | a |
| billion | B |
| billion tonnes | Bt |
| billion years ago | Ga |
| British thermal unit | BTU |
| centimetre | cm |
| cubic centimetre | $cm^3$ |

| | |
|---|---|
| cubic feet per minute | cfm |
| cubic feet per second | $ft^3/s$ |
| cubic foot | $ft^3$ |
| cubic inch | $in^3$ |
| cubic metre | $m^3$ |
| cubic yard | $yd^3$ |
| Coefficients of Variation | CVs |
| day | d |
| days per week | d/wk |
| days per year (annum) | d/a |
| dead weight tonnes | DWT |
| decibel adjusted | dBa |
| decibel | dB |
| degree | ° |
| degrees Celsius | °C |
| diameter | ø |
| dollar (American) | USD |
| dollar (Canadian) | CAD |
| dry metric ton | dmt |
| foot | ft |
| gallon | gal |
| gallons per minute (US) | gpm |
| Gigajoule | GJ |
| gigapascal | GPa |
| gigawatt | GW |
| gram | g |
| grams per litre | g/l |
| grams per tonne | g/t |
| greater than | > |
| hectare (10,000 $m^2$) | ha |
| hertz | Hz |
| horsepower | hp |
| hour | h |
| hours per day | h/d |
| hours per week | h/wk |
| hours per year | h/a |
| inch | in |
| kilo (thousand) | k |
| kilogram | kg |
| kilograms per cubic metre | $kg/m^3$ |
| kilograms per hour | kg/h |
| kilograms per square metre | $kg/m^2$ |
| kilometre | km |
| kilometres per hour | km/h |
| kilopascal | kPa |
| kilotonne | kt |
| kilovolt | kV |
| kilovolt-ampere | kVA |

| | |
|---|---|
| kilovolts | kV |
| kilowatt | kW |
| kilowatt hour | kWh |
| kilowatt hours per tonne | kWh/t |
| kilowatt hours per year | kWh/a |
| less than | < |
| litre | l |
| litres per minute | l/m |
| megabytes per second | Mb/s |
| megapascal | MPa |
| megavolt-ampere | MVA |
| megawatt | MW |
| metre | m |
| metres above sea level | masl |
| metres Baltic sea level | mbsl |
| metres per minute | m/min |
| metres per second | m/s |
| microns | µm |
| milligram | mg |
| milligrams per litre | mg/l |
| millilitre | mL |
| millimetre | mm |
| million | M |
| million bank cubic metres | $Mbm^3$ |
| million bank cubic metres per annum | $Mbm^3/a$ |
| million tonnes | Mt |
| minute (plane angle) | ' |
| minute (time) | min |
| month | mo |
| ounce | oz |
| pascal | Pa |
| centipoise | mPa·s |
| parts per million | ppm |
| parts per billion | ppb |
| percent | % |
| pound(s) | lb |
| pounds per square inch | psi |
| revolutions per minute | rpm |
| Ruble (Russian) | RUB |
| second (plane angle) | " |
| second (time) | s |
| short ton (2,000 lb) | st |
| short tons per day | st/d |
| short tons per year | st/y |
| specific gravity | SG |
| square centimetre | $cm^2$ |
| square foot | $ft^2$ |
| square inch | $in^2$ |

| | |
|---|---|
| square kilometre | $km^2$ |
| square metre | $m^2$ |
| three-dimensional | 3D |
| tonne (1,000 kg) (metric ton) | t |
| tonnes per day | t/d |
| tonnes per hour | t/h |
| tonnes per year | t/a |
| tonnes seconds per hour metre cubed | $ts/hm^3$ |
| volt | V |
| week | wk |
| weight/weight | w/w |
| wet metric ton | wmt |

### *Abbreviations and Acronyms*

| | |
|---|---|
| AACE International | AACE |
| acid rock drainage | ARD |
| acid rock drainage | ARD |
| acid-base accounting | ABA |
| acid-generating potential | AP |
| acid-generating potential | AP |
| Administration for Subsoil Use in the Republic of Sakha-Yakutia | YAKUTNEDRA |
| all-terrain vehicle | ATV |
| ammonium nitrate fuel oil | ANFO |
| atomic absorption | AA |
| Bond Abrasion Index | $BA_i$ |
| Bond Ball Mill Work Index | $BW_i$ |
| calcium carbonate | $CaCO_3$ |
| calcium hypochlorite | $Ca(OCl)_2$ |
| calcium oxide | CaO |
| Canadian Institute of Mining, Metallurgy and Petroleum | CIM |
| Canadian Security Administrators | CSA |
| Chemical Laboratory of the State Enterprise Aldangeologiya | Aldan Lab |
| chlorine | Cl |
| comma separated values file | .csv |
| cost breakdown structure | CBS |
| counter-current decantation | CCD |
| Crusher Work Index | $CW_i$ |
| cumulative net cash flow | CNCF |
| cyanide weak acid dissociable | $CN_{WAD}$ |
| Differential Global Positioning Systems | DGPS |
| engineering, procurement and construction management | EPCM |
| Enterprise resource plan | ERP |
| Environmental and Social Impact Assessment | ESIA |
| environmental protection plan | EPP |
| Environmental Resources Management Group Inc. | ERM |
| exploratory data analysis | EDA |
| Federal State Unitary Enterprise Central Institute of Science Research and Geological Surveying of Base and Precious Metals | TSNIGRI |

| | |
|---|---|
| Federal Subsoil Resources Management Agency | ROSNEDRA |
| Free Carrier | FCA |
| general and administration | G&A |
| General Seismic Zonation | GSZ |
| Geospark Core Database System™ | Geospark |
| GEOVIA Surpac | Surpac |
| global positioning system | GPS |
| Gosudarstvennyy Standart | GOST |
| gravity recoverable silver | GRS |
| greenhouse gas | GHG |
| hazard and operability | HAZOP |
| Health, safety, security and environment | HSSE |
| heavy liquid separation | HLS |
| high-density polyethylene | HDPE |
| Important Bird and Biodiversity Area | IBA |
| inductively coupled plasma | ICP |
| input/output | I/O |
| Intensive Leach Reactor | ILR |
| internal rate of return | IRR |
| International Building Code | IBC |
| International Electrotechnical Commission | IEC |
| International Finance Committee | IFC |
| International Finance Corporation | IFC |
| International Organization for Standardization | ISO |
| inter-ramp angles | IRA |
| inverse distance weighting squared | $IDW^2$ |
| ion exchange | IX |
| Key performance indicator | KPI |
| lead nitrate | $PbNO_3$ |
| lead | Pb |
| life-of-mine | LOM |
| load-haul-dump | LHD |
| local area network | LAN |
| London Bullion Market Association | LBMA |
| material take-off | MTO |
| maximum permissible concentrations | MPC |
| Medvedev-Sponheur-Karnik | MSK |
| metal leaching | ML |
| Mineable Shape Optimizer | MSOw |
| Mineral Resources Extraction Tax | MRET |
| Modified Mercalli Intensity | MMI |
| motor control centre | MCC |
| multiple linear regression | MLR |
| National Institute of Non-ferrous Metals | GINTSVETMET |
| National Instrument 43-101 | NI 43-101 |
| National Oceanic and Atmospheric Administration | NOAA |
| Neryungristroiizyskaniya | NSI |
| net cash flow | NCF |

| | |
|---|---|
| net neutralization potential | NNP |
| net present value | NPV |
| neutralization potential | NP |
| neutralizing potential | NP |
| non-potentially acid generating | NPAG |
| ordinary kriging | OK |
| peak ground acceleration | PGA |
| personal protective equipment | PPE |
| polyvinyl chloride | PVC |
| potentially acid generating | PAG |
| preliminary economic assessment | PEA |
| PricewaterhouseCoopers | PwC |
| programmable logic controller | PLC |
| project execution plan | PEP |
| Qualified Person | QP |
| quality assurance | QA |
| quality control | QC |
| Quantitative Evaluation of Minerals by Scanning | QEMSCAN® |
| quantitative kriging neighbourhood analysis | QKNA |
| rock quality designation | RQD |
| run-of-mine | ROM |
| SGS Vostok Limited | SGS Vostok |
| Silver Bear Resources Inc. | Silver Bear |
| silver nitrate | $Pb(NO_3)_2$ |
| silver | Ag |
| Special Protected Natural Area | SPNA |
| SRK Consulting (UK) Ltd. | SRK |
| standard reference material | SRM |
| State Unitary Enterprise | SUE |
| supervisory control and data acquisition | SCADA |
| System for Electronic Document Analysis and Retrieval | SEDAR |
| tailings management facility | TMF |
| TEO Conditsy Report | TEO |
| the Mangazeisky Project | the Project or the Property |
| TOMS Institute | TOMS |
| total cyanide | $CN_{TOTAL}$ |
| total suspended solids | TSS |
| Ulyanovsk Automobile Plant | UAZ |
| uninterruptible power supply | UPS |
| Universal Transverse Mercator | UTM |
| Value Added Tax | VAT |
| variable speed drive | VSD |
| very-high frequency | VHF |
| volatile organic compound | VOG |
| waste rock dump | WRD |
| water balance model | WBM |
| wildlife management area | WMA |

| | |
|---|---|
| work breakdown structure | WBS |
| World Geodetic System | WGS |
| World Health Organisation | WHO |
| x-ray diffraction | XRD |
| x-ray fluorescence | XRF |
| ZAO Prognoz | Prognoz |
| zinc | Zn |
| ООО “НСИ” | NCI |

# 1.0 SUMMARY

## 1.1 INTRODUCTION

The Mangazeisky Project (the Project or the Property) is a silver property located in the region of Yakutia, Republic of Sakha, Russia, and is 100% owned by ZAO Prognoz (Prognoz), a wholly-owned subsidiary of Silver Bear Resources Inc. (Silver Bear).

In August 2016, Silver Bear commissioned Tetra Tech to complete a National Instrument 43-101 (NI 43-101) compliant feasibility study update for the Project, focusing on the silver mineralization of the Vertikalny deposit. The study also restates the current Mineral Resource for the Nizhny Endybal deposit and the Mangazeisky North and South deposits, all of which are also located within the Property area.

The effective date of this study is 4th October 2016 and the effective date of the Vertikalny Mineral Resource estimate is 8th July 2016. All currency is reported in US dollars (USD), unless otherwise noted.

Shortly after the completion of the original feasibility study, new results from the ongoing geological field program became available that allowed the resource geologist to refine the geological model, to achieve better definition of the mineralised zones and significantly increase the Indicated Mineral Resource estimate. Silver Bear contracted Tetra Tech to complete an updated feasibility-level mine plan and Mineral Reserve estimate for the Project and to incorporate these changes into the financial model, such that an updated feasibility study can be published. The feasibility study update did not change any infrastructure items and the mine production rate was designed to match the process plant capacity.

The key outcomes of the Project are summarized in Table 1.1.

**Table 1.1 Mangazeisky Project Summary**

| Description | Unit | Value |
|---|---|---|
| Commodity | - | Ag |
| Mining Area | - | Vertikalny Deposit |
| Mining Method | - | Open Pit/Underground |
| Average Head Grade (LOM) | g/t Ag | 852 |
| LOM | years | 7.5 |
| Processing Method | - | Cyanide Leach with Direct Electrowinning |
| Product | - | Silver Powder (99.8% Ag) |
| Metallurgical Recovery | % | Oxide – 85.0<br>Primary – 69.6 |
| Total Initial Capital | $ million | 49.9 |
| Total LOM Capital | $ million | 65.2 |

*table continues...*

| Description | Unit | Value |
|---|---|---|
| Operating Cost | $/t processed | 158.84 |
| Silver Price (LOM Weighted Average) | $/t | 19.76 |
| Exchange Rate | RUB:USD | 66.00:1.00 |
| Pre-tax IRR | % | 86.1 |
| Pre-tax NPV (5%) | $ million | 132.62 |
| Pre-tax Payback (undiscounted) | years | 1.3 |
| Post-tax IRR (without the Far East Tax Incentives) | % | 56.1 |
| Post-tax NPV (5%) (without the Far East Tax Incentives) | $ million | 82.82 |
| Post-tax Payback (undiscounted) (without the Far East Tax Incentives) | years | 1.7 |
| Post-tax IRR (with the Far East Tax Incentives) | % | 81.9 |
| Post-tax NPV (5%) (with the Far East Tax Incentives) | $ million | 123.08 |
| Post-tax Payback (undiscounted) (with the Far East Tax Incentives) | years | 1.3 |

Notes: Ag – silver; LOM = life-of-mine; IRR = internal rate of return; NPV = net present value; USD – US Dollar; RUB – Russian Ruble

Tetra Tech led a group of qualified consulting companies, commissioned by Silver Bear, to complete component studies for the purposes of the feasibility study. Table 1.2 outlines the responsibilities of each company.

**Table 1.2 Consulting Company Responsibilities**

| Company | Responsibility |
|---|---|
| Tetra Tech | overall project management; property description and location; accessibility, climate, local resources; infrastructure and physiography; history; geological setting and mineralization; deposit type; exploration; drilling; sample preparation, analyses and security; data verification; adjacent properties; mineral resource estimates; mineral processing and metallurgical testing; recovery methods, logistical infrastructure; site layout; site access; site geotechnical; structural and architectural design basis; site roads; processing facility infrastructure; site facilities; remote site facilities; waste rock dumps, ore stockpiles and overburden storage area; site water management; waste and sewage; site storage; power supply and distribution; processing and general and administrative capital and operating cost estimates; economic analysis; project execution; mineral reserve estimates; mining methods; mining capital and operating costs |
| ERM | environmental studies, permitting, and social or community impact |
| SRK | mining geotechnical evaluation; TMF; tailings capital and operating costs; hydrology and hydrogeology |

Note: ERM = Environmental Resources Management Group Inc.; SRK = SRK Consulting (UK) Ltd.; TMF – tailings management facility

## 1.2 PROPERTY DESCRIPTION AND LOCATION

The Property is located approximately 400 km north of Yakutsk, in the Kobyask district, within the Republic of Sakha (Yakutia) (Figure 1.1). The Property longitude and latitude is approximately 65°40' south and 130°07' east.

The Property is defined by the mineral rights to a single mining license, and is 100% held by Prognoz, a private Russian closed-joint stock company based in Yakutsk. Prognoz is a 100% held subsidiary of Silver Bear.

The mining license, number YaKU 03626 BE, covers the entire Vertikalny silver deposit over an area of 13.55 km$^2$. The coordinates of the mining licenses are shown in

Table 1.3.

**Figure 1.1 Property Location Map**

Source: Silver Bear

**Table 1.3 Mining License Coordinates**

| Mining License YaKU 03626 BE | | |
|---|---|---|
| Corner No. | Northing Coordinate | Easting Coordinate |
| 1 | 65°41'15.917" | 130°01'55.380" |
| 2 | 65°41'41.938" | 130°03'23.150" |
| 3 | 65°41'37.066" | 130°04'59.859" |
| 4 | 65°41'20.210" | 130°06'27.196" |
| 5 | 65°40'08.102" | 130°08'20.361" |
| 6 | 65°39'44.803" | 130°08'11.742" |
| 7 | 65°39'40.272" | 130°07'17.802" |
| 8 | 65°39'46.221" | 130°05'22.190" |
| 9 | 65°39'54.675" | 130°03'29.389" |
| 10 | 65°40'11.350" | 130°01'57.673" |
| 11 | 65°40'46.388" | 130°01'42.001" |

The mining license is situated in the central west portion of the Endybal exploration license (also known as the Mangazeisky exploration license), number YaKU 12692 BP, and covers several other exploration targets and silver deposits over an area of 570 km$^2$. The coordinates of the exploration licence are shown in Table 1.4.

**Table 1.4 Exploration License Coordinates**

| Exploration License YaKU 12692 BP | | |
|---|---|---|
| Corner No. | Northing Coordinate | Easting Coordinate |
| 1 | 65°49'35" | 130°00'00" |
| 2 | 65°49'35" | 130°19'20" |
| 3 | 65°29'00" | 130°22'00" |
| 4 | 65°29'00" | 130°00'00" |

A summary of all existing licence information is detailed in Table 1.5.

**Table 1.5 Property Mineral Licences**

| Licence Name | Licence ID | Type | Area (km$^2$) | Issue Date | Expiry Date | Annual Fees (RUB) |
|---|---|---|---|---|---|---|
| Endybal Area (Mangazeisky) | YaKU 12692 BP | Geological Allotment | 570.00 | 28th September 2004 | 31st December 2016 | 153,900 |
| Vertikalny Deposit | YaKU 03626 BE | Licence to Use Subsoil | 13.55 | 31st August 2013 | 1st September 2033 | 110,771 |

## 1.3 GEOLOGY AND MINERALIZATION

### 1.3.1 REGIONAL GEOLOGY

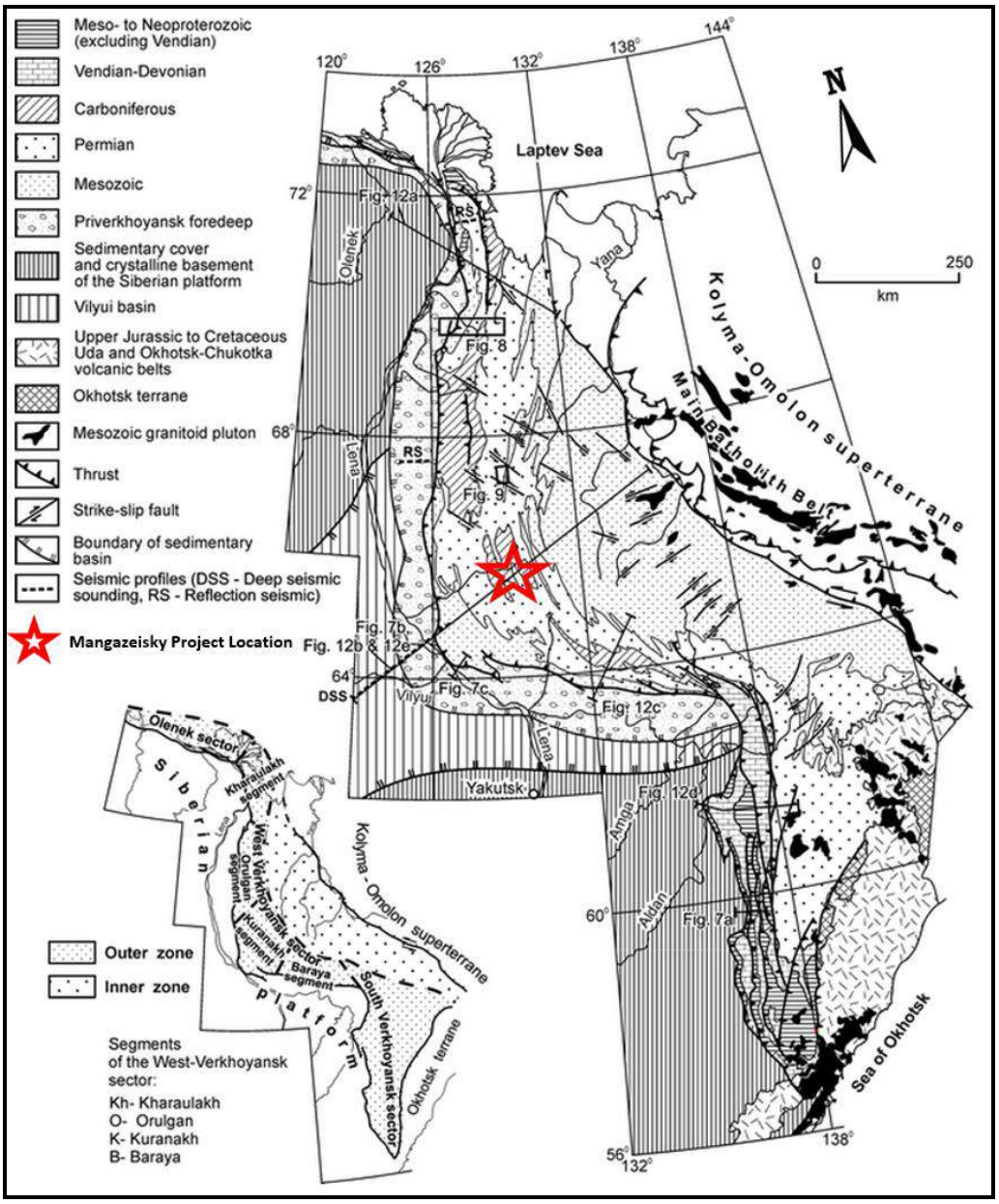
The Property is located within the Verkhoyansk mobile belt of north-eastern Yakutia. The fold-and-thrust belt forms part of a major orogenic system separating the Siberian North Asian Craton to the west from the immense expanse of accreted terranes that form most of the Russian Far East.

The belt extends for 2,000 km from the Laptev Sea to the Sea of Okhotsk. It is comprised of a greater than 7 km thick sequence of Late Precambrian to Triassic rocks deposited along the Palaeo-Pacific margin of the Siberian Craton, which developed because of rifting events during the Late Precambrian period and again during the Late Devonian to Early Mississippian periods.

Deformation during the Late Jurassic to Early Cretaceous occurred with low-grade metamorphism in the internal parts of the belt and the emplacement of high-level granitic bodies. Strike-slip faulting occurred during the Tertiary period.

The central part of the belt is dominantly comprised of a thick, monotonous succession of Carboniferous and Permian turbidites that are metamorphosed to lower-greenschist facies. Granodiorite and granite plutons have intruded the core of the belt and are associated with extensive gold-bearing quartz vein systems. Figure 1.2 presents the regional geology of the area.

**Figure 1.2 Regional Geology Map**




Source: Miller et al. (2002)

## 1.3.2 PROPERTY GEOLOGY

The mineral occurrences on the Property are located in the interfluve of the Nuektame and Arkachan rivers and range from the mid-channel of the Muhalkan River to the mouth of the Mysovoi Stream. The mineral deposits are confined to the eastern wing of the Kuranakhsky anticlinorium and are situated within the contours of the Endybal anticline.

Higher order asymmetric anticlinal and synclinal folds, that are 2 to 20 km in length, complicate the hinge portion of the Endybal anticline. The Mukhalkansky anticline with a north-northwest strike (340°) and the Mangazeisky syncline, which are adjacent on the western side, complicate the eastern wing of the Endybal anticline.

The dip of the rocks of the Endybal anticline in the area of the Mangazeisky deposits averages 20 to 45°.

Two north-south zones of faulting are distinguished. The most important is the Nuektaminsky shear zone, which limits the expansion of mineralisation to the east.

The movement along the Nuektaminsky fault is left-lateral. The next is the Granichny shear zone with right-lateral movement. The Granichny fault is a splay off the Nuektaminsky fault and together they form a V-shape, which represents a zone of tension. The Granichny shear zone hosts two vertical deposits (Semenovsky and Granichny) that cross-cut the stratigraphy.

The silver mineralisation is epigenetic. This is particularly clear at the Nizhny Endybal deposit, where the mineralised strata-bound zones exhibit structural deformation. The strata-bound veins and cross-cutting fracture systems in the region are associated with shearing. This is reflected in the common occurrence of parallel layers of slip planes along the boundaries of the sandstone beds and selvages of strata-bound veins, such as Mikhailovsky, Olgina, Vasilievsky, and Anglesite-Cerussite. The structural analysis of joints in the mineralised rocks shows the ubiquitous existence of overthrusting dislocations (Kostin et al. 1997).

The Endybal diatreme and quartz porphyry dykes postdate the overthrust event. The geological studies by Yangeologia (2000) and Kostin et al. (1997) have led to the following conclusions regarding the sequence of events:

1. mineralised layers of sandstone containing sulphide mineralisation
2. structural deformation
3. Endybal diatreme.

### 1.3.3 MINERALISATION

This region of Yakutia is known to contain many silver deposits. Figure 1.1 illustrates the position of the Property in relation to a number of the known silver projects in the region.

The Property contains several explored areas that host more than 100 occurrences of mineralisation. The mineral occurrences are concentrated within a 35 km long corridor. These main mineralised areas include: Yasny, Burny, Mukhalkansky, Zabyty, Zabyty-2, Mangazeisky, Strezhevoy, Vertikalny, Porfirovy-Borisovsky, Vostochny, Nizhny Endybal (NizhneEndybal), VerkhneEndybal, Jilny, Bezymyanny, Orogondia, and Kis-Kuel.

The Property hosts at least four different types of mineralisation:

- Strata-bound silver-bearing, quartz-carbonate-sulphide structures with average grades greater than 900 g/t silver, with lead and zinc by-products. These silver bearing structures were mapped and sampled over an area of 65 km$^2$. Examples of this are the Vasilievsky-Anglesite-Cerussite and Olgina-Mikhailovsky veins within the Mangazeisky North Zone.

- Thicker linear-type stockwork areas with carbonate-silver sulphosalt mineralisation. Examples of this occur in the Strezhevoy and Nizhny Endybal Zones.
- Narrow, steep dipping veins such as Vertikalny that cross-cut stratigraphy and feature grades in excess of 1,000 g/t silver over widths ranging from several centimetres to several metres. Vertikalny and possibly Zabytoe and Kis-Kuel are examples of this style of mineralisation.
- A porphyry area associated with quartz, quartz-carbonate and quartz-sulphide veins and veinlets, hosted by extrusive rhyolite porphyry. Porfirovy is an example of this.

## 1.4 EXPLORATION

Table 1.6 provides a summary of the exploration completed since 2007.

Early exploration focused upon the narrow, strata-bound silver mineralisation of the Vasilievsky and Mikhailovsky targets, with more of a focus on Vertikalny from 2007 onwards. Latterly, the exploration has incorporated the evaluation of the thicker, linear, stockworks at Sterzhnevoy and Nizhny Endybal.

**Table 1.6 Historic Exploration Activities at the Property**

| Year | Exploration Activities | Targets Explored |
|---|---|---|
| 2004 | No exploration was undertaken during 2004, other than a minor drilling campaign. | - |
| 2005 | 9,641 m³ of trenching. | Vasilievsky, Mikhailovsky, Sterzhnevoy, Nizhny Endybal |
| 2006 | 4,843 m³ of trenching and mapping. | Nizhny Endybal, Vostochny, Sterzhnevoy, Vertikalny |
| 2007 | 8,000 m³ of trenching. | Vertikalny |
| 2008 | 22,633 m³ of trenching.<br>Mapping, lithochemical sampling, direct current induced polarisation/magnetotellurics and magnetic anomaly geophysical surveys. | Vertikalny, Zabyty, Zabyty-2, Kis-Kuel, Orogondia |
| 2009 | 15,067 m³ of trenching.<br>Lithochemical sampling, magnetic anomaly mapping. | Nizhny Endybal, Vertikalny, Kis-Kuel, Mukhalkan-Burny |
| 2010 | No exploration was undertaken during 2010. | - |
| 2011 to 2012 | 1,600 m³ of trenching. | Nizhny Endybal |
| 2013 | 11,200 m³ of trenching. | Mangazeisky North |
| 2014 | 11,148 m³ of trenching. | Vertikalny, Mangazeisky, Porfirivoy, Sterzhnevoy. |
| 2015 | Eight trenches for a total length of 598 m. | Porfirivoy & Sterzhnevoy. |

Tetra Tech is of the opinion that the exploration has generally been conducted using methods and procedures that are consistent with recognised industry best practices. Some bias was noted when comparing the trenches with nearby drillholes and as a result some of the trenches were re-sampled using a circular saw to cut channels.

Following the re-sampling, the bias remained and it is therefore thought that this increase in grade is associated with some natural mechanical enrichment at surface. The trenches have been used for grade estimation in the Mineral Resource. All trenches are now channelled with circular saw.

## 1.5 DRILLING

Details about the drilling campaigns completed prior to 2010 have been disclosed fully in the Wardrop (2011). The 2011 to 2012 drilling campaigns have been disclosed fully in Tetra Tech (2013). The details of the drilling at Mangaziesky North completed during 2015 are disclosed in the 2016 Technical Report (Tetra Tech 2016). All of these reports are filed under Silver Bear's profile on SEDAR. Table 1.7 provides a summary of the drilling completed between 2004 and 2015. The 2015 drilling campaign at Vertikalny Central is described fully in Section 10.0.

**Table 1.7 Summary of Drilling on the Property**

| Year | Metres Drilled | Targets Drilled |
|---|---|---|
| 2004 | 151 | Vertikalny |
| 2005 | 3,370 | Vasilievsky, Mikhailovsky, Nizhny Endybal, Strezhevoy |
| 2006 | 732 | Vertikalny |
| 2007 | 3,100 | Vertikalny |
| 2008 | 11,663 | Vertikalny, Semenovsky, Vasilievsky |
| 2009 | 12,373 | Vertikalny |
| 2010 | - | No drilling undertaken |
| 2011 to 2012 | 13,445 | Vertikalny, Nizhny Endybal |
| 2013 to 2014 | 9,153 | Mangazeisky, Vertikalny |
| 2015 | 4,427 | Vertikalny North West, Mangazeisky North, Porphivory, Strezhevoy |

Tetra Tech is of the opinion that drilling has generally been completed using methods and procedures that are consistent with recognised industry practices and that the data is adequate for Mineral Resource estimation.

## 1.6 MINERAL PROCESSING AND METALLURGICAL TESTING

As part of the feasibility study, mineralogical and metallurgical test work was completed at two commercial laboratories; SGS Vostok Limited (SGS Vostok) (Chita, Russia) and TOMS Institute (TOMS) (Irkutsk, Russia).

SGS Vostok tested a composite sample, which comprised samples collected from dedicated metallurgical drillholes within the Central Zone of the orebody representing the oxide ore. The SGS Vostok test work was completed between January 2014 and December 2014.

TOMS completed two separate test work programs in 2015. TOMS initially completed a leach variability test program in February 2015, followed by leach optimisation and

comminution test work for a primary ore composite. The primary ore testing was completed between November 2015 and December 2015.

Tetra Tech analysed all the metallurgical test work results with the objective of identifying the optimal process flowsheet. The metallurgical studies indicate that the oxide ore is amenable to gravity concentration and cyanidation and can be efficiently processed using a gravity and agitated tank leach based flowsheet. The studies also indicate that the primary ore is amenable to cyanidation and can be effectively processed by a whole ore leach method.

Based on the metallurgical and mineralogical test work, the average silver recovery is expected to be 85.0% for oxide ore and 69.6% for primary ore.

## 1.7 MINERAL RESOURCE ESTIMATES

### 1.7.1 MINERAL RESOURCE STATEMENT

Tetra Tech completed a new Mineral Resource estimate for the Vertikalny deposits, with an effective date of 8th July 2016. The most recent data included in the estimate was received on 1st July 2016. Mr. Robert Davies, BSc, EurGeol, CGeol, an independent Qualified Person (QP) as defined by NI 43-101, estimated the Mineral Resources.

This section also presents a re-statement of the Mineral Resource for the Nizhny Endybal deposit, situated approximately 2.5 km east of the Vertikalny deposit, and the Mangazeisky North deposits located 7 km to the north of Vertikalny.

The effective date of the Nizhny Endybal Mineral Resource is 11th September 2012. Mr. P. Gribble, FIMMM, CEng, former Senior Geologist at Tetra Tech, is the independent QP who originally prepared the Nizhny Endybal Mineral Resource estimate. Mr. Davies has reviewed and verified the Nizhny Endybal Mineral Resource estimate as current.

The effective date of the Mangazeisky North Resource is 31st March 2016. The effective date of the Mangazeisky South Resource is 3rd June 2015. The Mineral Resources have been estimated by Mr. Robert Davies.

Further details of the Nizhny Endybal and Mangazeisky North Mineral Resource estimates are publically available in technical reports prepared by Tetra Tech and filed under the Silver Bear profile on the System for Electronic Document Analysis and Retrieval (SEDAR), in 2012, 2015, and 2016.

A summary of the current Mineral Resources for the Property are presented in Table 1.8.

**Table 1.8 Total Resources for the Mangazeisky Property**

| Zone | Assumed Mining Method | Cut-off Grade Ag (g/t) | Indicated Resources | | | Inferred Resource | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) |
| Vertikalny Central | Open Pit | 200 | 360,000 | 1,482 | 17,100,000 | 4,000 | 496 | 100,000 |
| | Underground | 350 | 340,000 | 959 | 10,600,000 | 350,000 | 789 | 8,800,000 |
| Vertikalny Northwest | Open Pit | 200 | | | | 110,000 | 430 | 1,600,000 |
| | Underground | 350 | | | | 90,000 | 535 | 1,500,000 |
| Nizhny Endybal | Open Pit | 150 | | | | 710,000 | 316 | 7,200,000 |
| Mangazeisky North | Open Pit | 150 | 304,000 | 626 | 6,100,000 | 98,000 | 671 | 2,100,000 |
| Mangazeisky South | Open Pit | 150 | | | | 60,000 | 246 | 500,000 |
| **Total** | **All** | - | **1,004,000** | **1,046** | **33,800,000** | **1,422,000** | **477** | **21,800,000** |

### 1.7.2 SUMMARY OF ESTIMATION TECHNIQUES

Tetra Tech created wireframe models using Leapfrog Geo (version 3.1). Wireframes were created to represent lithologies, oxidation state, and mineralised bodies. Wireframes were developed for strongly mineralised core zones and where present, less strongly mineralised wall rock alteration (as described in Section 14.2.1). Variography, block modelling and Mineral Resource estimation were completed in GEOVIA Surpac™ software (version 6.7).

The silver grades for the Vertikalny Central and Northwest zones were estimated using Ordinary Kriging (OK) interpolation methodology. Density for the Central Zone was estimated using Inverse Distance Weighted Squared ($IDW^2$), while density was assigned for the Northwest Zone.

Statistical and grade continuity analyses were completed in order to characterise the mineralisation, and were subsequently used to develop grade interpolation parameters. Grade estimation was completed using OK. The search ellipsoid dimensions and orientations were chosen to reflect the continuity revealed by geostatistical studies. Block size, discretisation, search size, and sample numbers were optimised using Quantitative Kriging Neighbourhood Analysis (QKNA).

Tetra Tech adopted the definition of Mineral Resources as outlined within the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) Definition Standards on Mineral Resources and Mineral Reserves (CIM 2014) in order to classify the Mineral Resources.

In order to demonstrate that the deposit has reasonable prospects for economic extraction, a cut-off grade of 200 /t silver has been applied for Mineral Resources contained within an open pit shell at Vertikalny Central, or within 80 m of surface at Vertikalny Northwest. A 350 g/t silver cut-off has been applied for the underground Mineral Resource, based upon the following assumptions:

- silver price of USD17.00/troy oz
- mining cost USD2.53/t open pit and USD70.00/t underground
- processing cost of USD52.00/t
- general and administrative (G&A) costs of USD40.60/t.

At Vertikalny Central, a pit shell wireframe was used to constrain the open pit resource in order to demonstrate that the resource has reasonable prospects for economic extraction. The pit shell was developed using the following assumptions:

- silver price of USD19.00/troy oz
- mining recovery 95%
- waste dilution 30%
- mining cost of USD2.53/t
- processing cost of USD52.00/t
- G&A costs of USD40.60/t

- royalty of 6.5%
- overall silver recovery of 88%.

In order to demonstrate that the deposit has reasonable prospects for economic extraction, a cut-off grade of 150 g/t was applied for the Mangazeisky North and Nizhny Endybal deposits, based upon the following assumptions:

- forecasted silver price of USD17.00/troy oz
- open pit mining cost of USD3.16/t
- processing cost of USD50.00/t
- G&A costs of USD12.50/t
- transport costs, from pit to process plant, of USD3.60/t
- overall silver recovery of 80%.

## 1.8 MINERAL RESERVE ESTIMATES

The Mineral Reserve was estimated in accordance with the CIM Definition Standards for Mineral Resources and Mineral Reserves (prepared by the CIM Standing Committee on Reserve Definitions, Adopted by CIM Council on November 27, 2010). According to the CIM, a Mineral Reserve is the economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a prefeasibility study. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined. The Mineral Reserve is inclusive of the reported Mineral Resource.

Proven and Probable Mineral Reserves for the Vertikalny deposit are presented in Table 1.9.

**Table 1.9 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016**

| Category | Cut-off Grade (g/t Ag) | Ore (t) | Ag Grade (g/t) | Ag Metal Content (koz) |
|---|---|---|---|---|
| Probable – Open Pit | 250 | 364 | 1,209 | 14,144 |
| Probable – Underground | 450 | 458 | 569 | 8,375 |
| **Total Mineral Reserves** | - | **822** | **852** | **22,519** |

## 1.9 MINING METHODS

### 1.9.1 OPEN PIT

GEOVIA Whittle™ software was used to carry out the pit optimisation and to define the optimal economic boundary for the open pit. GEOVIA GEMS™ software was also used for the pit and waste rock dump (WRD) designs and for preparation of the end-of-period pit plans and rock inventory estimation.

In both the optimisation and pit design the SRK geotechnical study and slope configuration results (Appendix B) were applied. Note that whereas the North Pit was designed using two phases, the South Pit has only one phase.

A sensitivity analysis on the selected pit shell for the base case shows that the orebody within the selected shell is most sensitive to process recovery and silver price, while the sensitivity of the cash flow to the mining cost and processing cost is minimal.

The total in situ mineralised rock above cut-off grade (240 g/t silver) within the designed pits is 292 kt, at an average silver grade of 1,581 g/t. The total low-grade material and waste rock is 10.4 Mt and the total rock is 10.7 Mt. The North Pit contains 70% of total rock and 80% of silver in the open pits. The average grade of the orebody, within the designed North Pit, is approximately 25% higher than the average grade in the South Pit.

The LOM production schedule was developed by preparing approximate pit plans for the end of each quarterly period for the first nine quarters from October 2016 to the end of 2018, plus the pit plan for the end of 2019. The final mining period in 2020 will deplete the remaining rock in the North Pit. Once the rock inventory within the prepared plans was estimated, mining dilution and losses were applied, and the monthly schedule was prepared until the end of 2018. The rock inventory for the 2019 pit plan was used for preparing the quarterly schedule for the open pit in that year.

The mining operation is scheduled to start in Q4 2016 with three months of pre-stripping prior to full operation. The ramp-up schedule for the process plant production starts in Q1 2017 and is assumed to be a three-month period, where a total of 21 kt will be delivered to the process plant. Beyond the Q1 2016, the process plant will reach the nominal capacity of 110 kt/a or 27.5 kt per quarter. The process plant throughput will be provided from direct haulage of run-of-mine (ROM) material, or from a combination of ROM and reclaimed stockpiled material. For the updated production schedule, the higher grade stockpiled ore will be utilised to delay the delivery of the lower grade ROM ore to the process plant, or to supplement feed when there is, insufficient exposed ore in the working benches during any given period.

The mining and ancillary fleet comprise 1.9- to 2.4-$m^3$ backhoe excavators, 20-t trucks, and a downhole drill capable of drilling 76-mm blastholes. Other earthmoving and support equipment have been estimated as ancillary equipment, requiring three drills, three excavators, 10 trucks, 4 dosers, and 2 road graders as the main mining equipment selected for this operation.

### 1.9.2 Underground Mining

Tetra Tech recommends mechanised sub-level open stoping, with remote stope cleaning, as the safest and most productive underground mining method for the Vertikalny deposit. This method is preferred as it is particularly suited for narrow vein, steeply dipping, hard rock mineralisation geometries. The implementation of this method has become more practical with the advent of mining equipment technologies that have are compact and can be operated remotely. Mine simulations show that slightly higher dilution can be expected in in sub-level open stoping when

compared to shrinkage stoping, but that this drawback is overshadowed by the benefit of lower underground unit operational costs.

All lateral development will be completed using an electrically-powered, single boom jumbo drill rig, with ventilation raises developed using a long-hole drill rig (stoping drill rig). The underground Mineral Reserve will be exploited in two distinct underground mining areas in the north and south, each with each own independent ramp access. This takes into account the stopes' proximity to surface and the open pit, and the operational flexibility provided by mining multiple deposits with a single fleet of mobile equipment. For the South Zone, adit accesses were designed for some of the sub-levels, with access from a surface road and from within the South Pit. As the underground access ramps and adits will be tied into the open pit designs, the timing of their development will be contingent on the open pit mining schedule.

## 1.10 RECOVERY METHODS

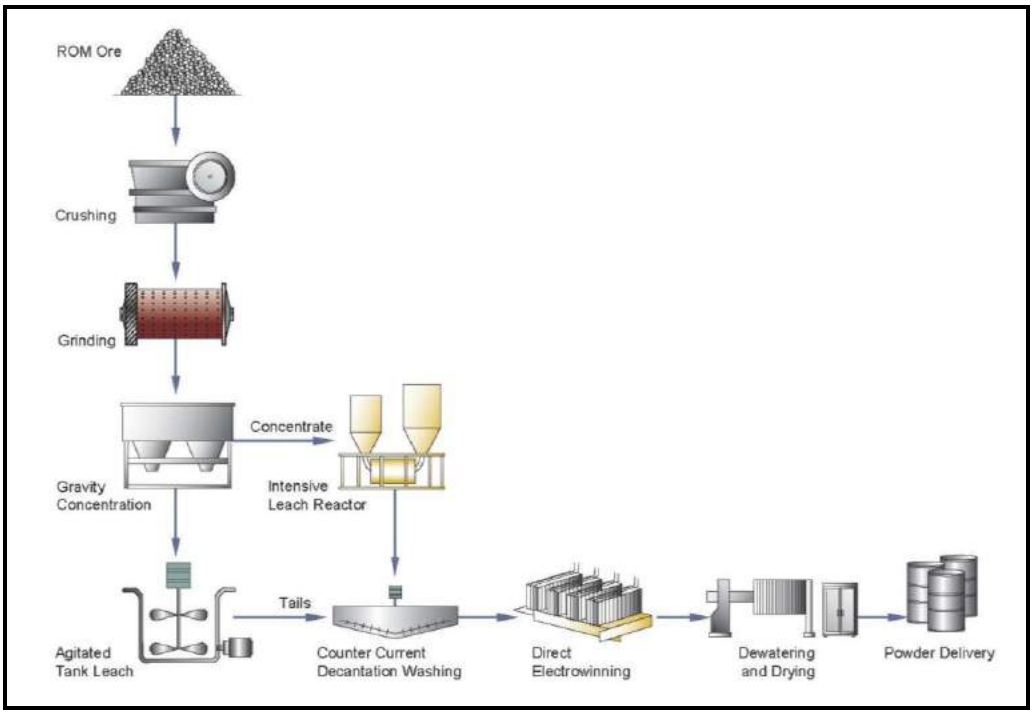
The process design was based on the completed metallurgical test work, with the objective of developing a flowsheet that is simple as possible to supply, operate, and maintain, while still maximising silver recovery and minimising power requirements.

The process plant is designed to treat 110,000 t/a of ore with an average LOM silver grade of 772 g/t. The plant is expected to achieve an 85.0% silver recovery oxide ore and 69.6% of fresh ore. The treatment of fresh ore will be deferred to the last year of the production schedule and not processed in combination with the oxidised material.

The process flowsheet consists of a standard crushing and milling circuit, followed by gravity concentration and agitated tank leach of the gravity tails. The gravity concentrates will be processed by intensive cyanidation. The leached slurry from the tank leach and intensive cyanidation will go through a simple counter current decantation washing system and the pregnant solution, at a LOM average silver grade of approximately 600 ppm, will be processed by direct electrowinning to recover silver metals.

A conceptual block flow diagram of the proposed process plant is shown in Figure 1.3.

**Figure 1.3 Conceptual Process Block Flow Diagram**




Source: Tetra Tech

Tailings from the process plant will comprise filtered solids and a blead stream from the depleted electrowinning solution, and will be disposed of in the TMF.

## 1.11 PROJECT INFRASTRUCTURE

### 1.11.1 GENERAL

The Project will require the development of a number of infrastructure components. The locations of project facilities and other infrastructure items were selected to take advantage of local topography, accommodate environmental considerations, and ensure efficient and convenient operation of the mine haul fleet.

Project infrastructure will include:

- airstrip
- off-site, on-site, and service road access
- mine haul roads
- TMF
- WRD, crushed ore stockpile, and ROM pad
- camp flood protection berms
- borehole water supply and distribution system
- water treatment and distribution
- sewage collection and management

- surface water management
- process and ancillary facilities, including:
  - process plant
  - crushing facility
  - reagent storage and handling
  - facilities for administration and an assay laboratory
  - heavy and light vehicle workshops
  - fuel storage and distribution
  - explosives storage and handling
  - emergency helipad
  - camp accommodation
  - mess and laundry facilities
  - medical centre
- power supply and local distribution network
- communications infrastructure.

The site layout (Figure 1.4) displays the location and orientation of the three main mine site components:

- the Vertikalny open pit area and underground mine
- the process plant facility
- the supporting site infrastructure which encompasses all roads, buildings, facilities, and structures that support—but do not directly contribute to—the primary purpose of the mining operation.

Figure 1.5 shows the layout of the process plant complex.

### 1.11.2 TAILINGS MANAGEMENT FACILITY

The TMF will consist of a dry stack facility, contained within a fully-lined pad, surrounded by a series of containment bunds. A clarification pond to store all process affected fluids before retreatment is included in the design.

SRK undertook a TMF site selection study, in which a series of four alternative locations were assessed for development. A waste rock and tailings co-disposal option was also considered as part of this assessment.

The TMF will be constructed 0.2 km northeast of the plant site, and will cover an area of 7.69 ha (Figure 1.5). Approximately 0.8 Mt of tailings material will require storage over the LOM.

**Figure 1.4 Site Infrastructure Layout**

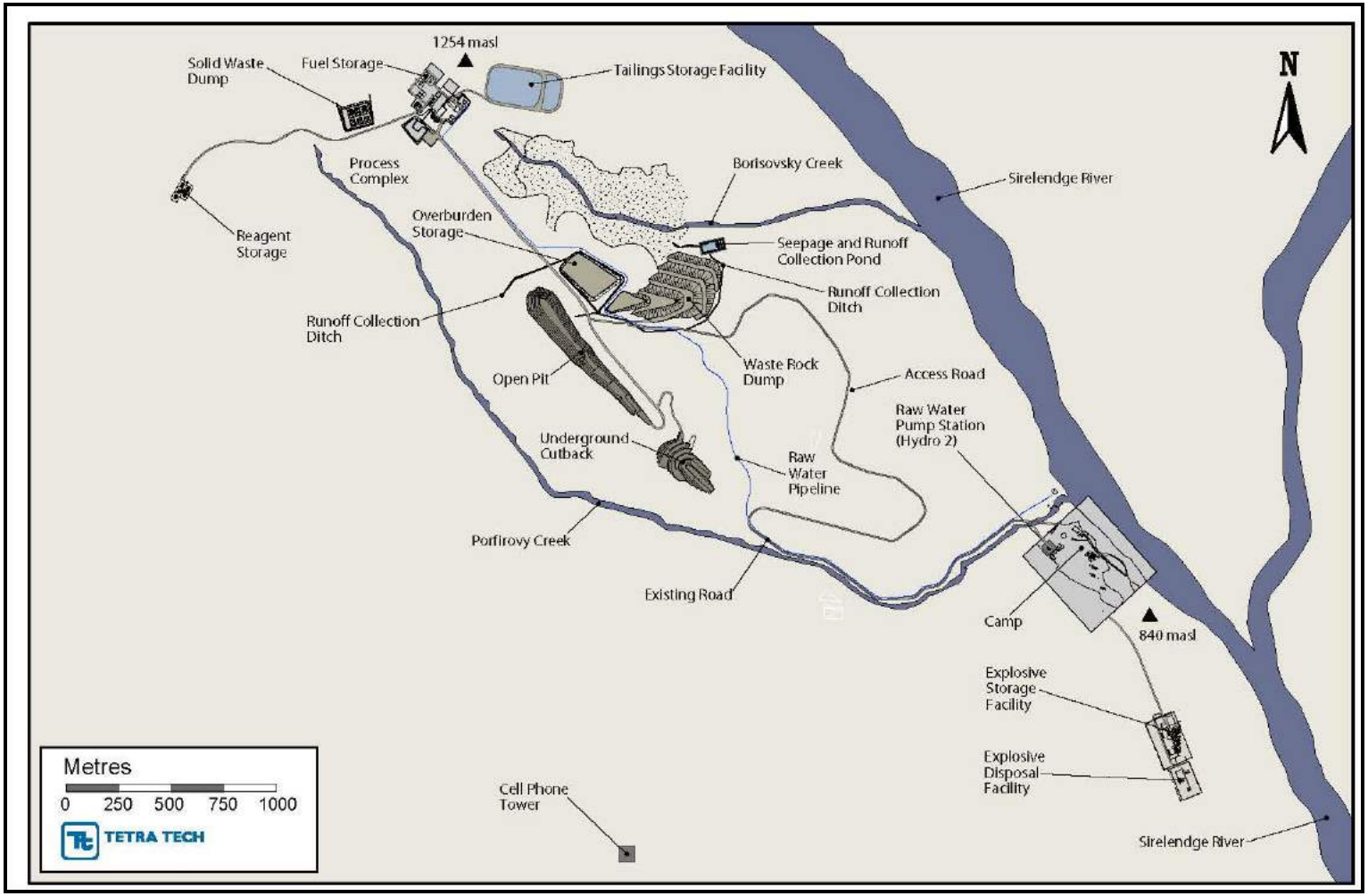
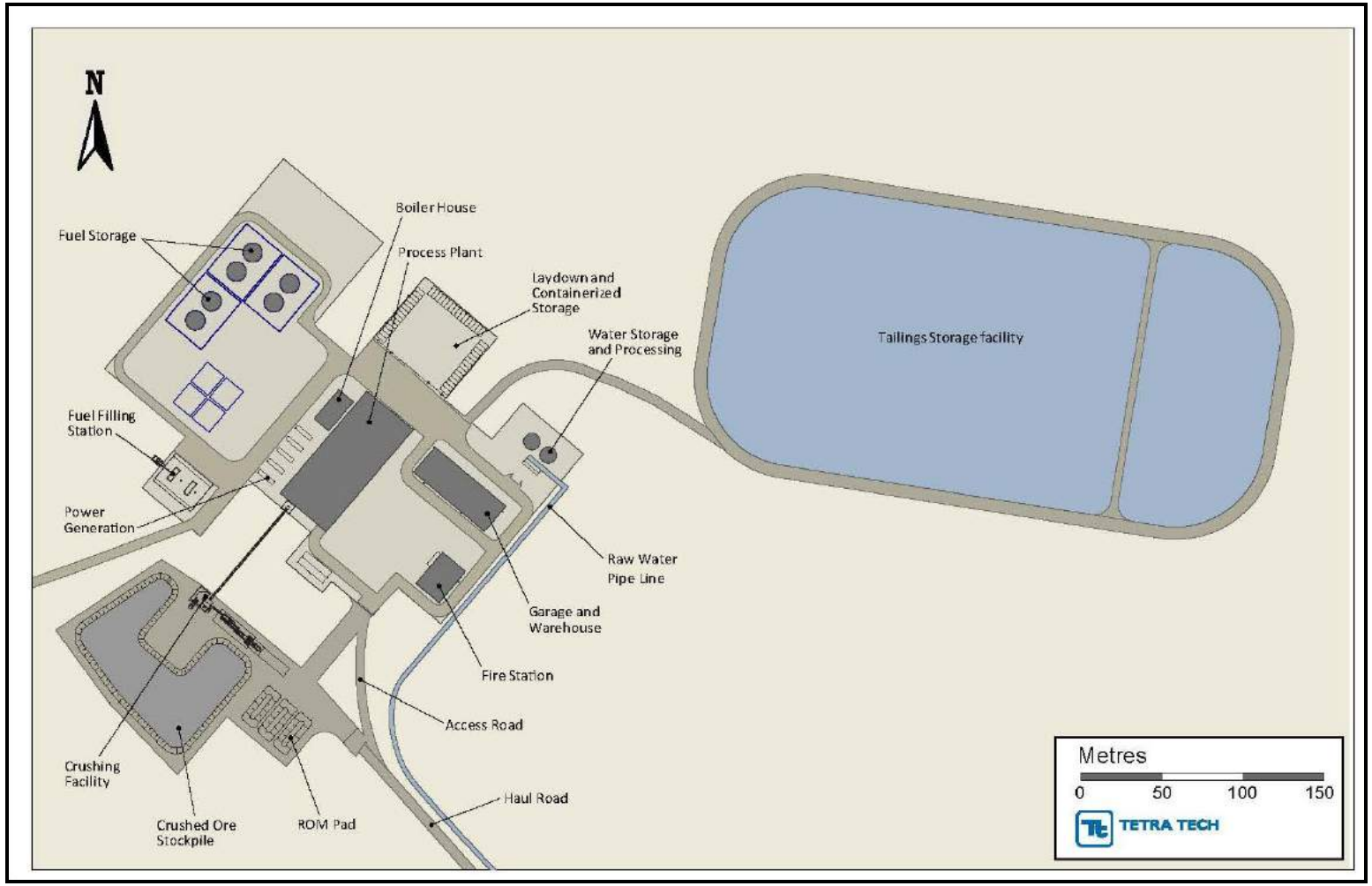


**Figure 1.5 Process Plant Facility Layout**



### 1.11.3 WINTER ROAD

The area is serviced by a number of public winter roads serving villages on route to site. The current haulage route is 570 km long. Based on the last five years of moving consumables and heavy equipment to site, a one-way trip takes, on average, two days.

The local Sakha authority is responsible for determining when the road is open and granting permission for the road to be used. Road maintenance is undertaken by specialist contractors under the direction of Prognoz, with the maintenance burden increasing in line with road usage. Maintenance begins in September to prepare for the official opening of the road on 1st January.

Early in the season the road opens with a 5-t weight limit and, as the ice thickens, weight limits are raised to 10 t, and finally 20 t, although heavier loads can be transported by special arrangement. For general site deliveries, a size limit of 12 m (a 40 ft container) and a load weight limit of 14 t is recommended before special measures are taken.

Historically, Silver Bear has moved up to 50-t payloads on the winter roads for one-off special loads, such as a Caterpillar D9 bulldozer. For the 2015/2016 winter road season, the road was upgraded to provide a reliable route for process equipment delivery, in addition to regular bulk deliveries of construction material, spares, and consumables.

As part of the logistics supply line, upgrading of the Batamai Port on the northern bank of the Lena River will enable containerised consumables such as reagents, along with fuel, to be stockpiled during the summer months for haulage along the winter road. This will reduce the current haulage distance of 570 km to 370 km, reduce turnaround time from approximately six days to three days, and extend the transport window.

## 1.12 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

The Project is in the early stages of the Russian review and approval process. As part of this process, the environmental and social aspects of the Project will be evaluated by the Russian regulatory authorities. There can be no guarantees that the Project will be approved under Russian law, the timeline for any decision, and if the Project is approved, that there won't be terms and conditions that will have a material impact on the feasibility of the Project.

The assessment of potential effects of the Project, the development of mitigating and management measures, and the establishment of monitoring programs embedded in the feasibility study are preliminary and are expected to evolve over time. The results of ongoing work, including ongoing environmental studies, stakeholder engagement, and permitting have the potential to influence the design, operations, and economic results of the Project.

The Project execution plan and schedule has been de-coupled from permitting activities. Construction activities are being undertaken without the necessary permits in place. Further, the commencement of mining is planned for Q4 2016 and ore processing in Q12 2017, whereas there is a high risk based on the current status that permits will also not be in place to support these operating stage activities by the dates assumed in the feasibility study. In addition to real or perceived risks to safety and/or the environment, conducting these current and future activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material.

## 1.13 CAPITAL AND OPERATING COST ESTIMATES

### 1.13.1 CAPITAL COST ESTIMATE

The total estimated initial capital cost for the design, construction, installation, and commissioning of all facilities and equipment is $49.9 million. A summary breakdown of the capital cost is provided in Table 1.10.

**Table 1.10 Capital Cost Summary**

| Area | Initial ($) | Sustaining ($) | Total ($) |
|---|---|---|---|
| Mining | 2,657,838 | 12,311,588 | 14,969,426 |
| Processing | 14,344,727 | 700,000 | 15,044,727 |
| Infrastructure | 3,717,106 | - | 3,717,106 |
| Utilities | 1,639,171 | - | 1,639,171 |
| TMF | 1,104,096 | 1,325,776 | 2,429,171 |
| Site Facilities | 5,360,289 | - | 5,360,289 |
| Off-site Facilities | 101,454 | - | 101,454 |
| Project Indirects | 11,194,311 | 70,867 | 11,265,178 |
| EPCM | 3,525,492 | 20,248 | 3,545,740 |
| Owner's Cost | 3,850,690 | 100,000 | 3,950,690 |
| Allowances | 2,374,759 | 831,232 | 3,205,991 |
| **Total** | **49,869,933** | **15,359,711** | **65,229,644** |

Note: EPCM = engineering, procurement, and construction management

This estimate includes direct field costs required to execute the Project, plus indirect costs associated with design, construction and commissioning. This estimate is based on pricing as of Q3 2015, with no allowances for inflation or escalation. Elements of actual expenditures have been included, which further reduce the exposure to inflation or escalation. All currencies in this capital cost estimate is expressed in US dollars, unless otherwise noted.

### 1.13.2 OPERATING COST ESTIMATE

The LOM operating cost estimate for the Project consists of mining, processing, and G&A costs (which includes TMF and site water management costs) and is estimated at $158.83/t processed. Table 1.11 summarises the unit operating costs of each area.

**Table 1.11 LOM Averaged Operating Cost Summary**

| Area | Unit Cost ($/t processed) |
|---|---|
| Mining | 59.61 |
| Processing | 57.06 |
| G&A | 42.16 |
| **Total** | **158.83** |

## 1.14 ECONOMIC ANALYSIS

An economic evaluation was prepared for the Project based on a pre-tax financial model. The base case uses a variable silver price of $19.65/oz, $18.57/oz, $19.62/oz, $19.79/oz, $19.72/oz, and $19.92/oz during Q1 2017, Q2 2017, Q3/4 2017, 2018, 2019, and 2020, as well as the remaining project life, respectively, with a life-of-mine (LOM) weighted average silver price of US$19.76/oz. The exchange rate applied in the base case is RUB66.00/USD1.00. All currency units are US dollars unless otherwise specified. For the 7.5-year LOM and 822,000 t Mineral Reserve, the following pre-tax financial parameters were calculated:

- 86.1% internal rate of return (IRR)
- 1.3-year payback on the $50 million initial capital
- $133 million net present value (NPV) at a 5% discount rate.

Silver Bear commissioned PricewaterhouseCoopers (PwC) in Toronto, Canada, to prepare tax calculations for use in the post-tax economic evaluation of the Project with the inclusion of applicable Russian income and mining taxes. PwC estimated the applicable taxes in two cases. The first case does not account for the Far East Tax Incentives and the second case takes into account the Far East Tax Incentives (refer to Section 22.4 for further details). The following post-tax financial results were calculated for the base case without considering the Far East Tax Incentives:

- 56.1% IRR
- 1.7-year payback on the $50 million initial capital
- $83 million NPV at a 5% discount rate.

The following post-tax financial results were calculated for the base case when considering the Far East Tax Incentives:

- 81.9% IRR
- 1.3-year payback on the $50 million initial capital
- $123 million NPV at a 5% discount rate.

Sensitivity analyses were conducted to analyse the sensitivity of the Project merit measures (NPV, IRR, and payback periods) to the main inputs such as silver price, exchange rate, capital costs, and on-site operating costs. The Project's pre-tax NPV,

calculated at a 5% discount rate, is most sensitive to silver price followed by exchange rate, on-site operating costs, and capital costs. The Project's pre-tax IRR is most sensitive to silver price followed by exchange rate, capital costs, and on-site operating costs. The payback period is most sensitive to silver price and exchange rate, followed by capital costs and on-site operating costs.

## 1.15 PROJECT EXECUTION PLAN

The execution strategy for the successful monitoring and control of the Project reflects a modification to the traditional EPCM approach to project execution. Silver Bear will manage the completion of the Project with the input from various engineering companies, including Russian-based companies, who will complete the bulk of the detailed engineering, and international engineering firms, who will provide engineering review and specialist metallurgical input. Silver Bear will be responsible for the project management, procurement, and construction management using in-house resources. Short lines of decision making will be used to execute this fast-track project.

The Silver Bear execution strategy will be built on a lean, fit-for-purpose approach that favours self-sufficiency in execution and operation.

## 1.16 RISKS AND OPPORTUNITIES

### 1.16.1 RISKS

The most significant risks related to project execution (identified as critical risks) are shown in the risk matrix with their mitigation strategies in Table 1.12.

**Table 1.12 Critical Risks**

| Risk | Impact | Mitigation |
|---|---|---|
| Delay in critical mechanical equipment fabrication leads to late delivery. | Equipment delivery may miss winter road period and delay the project by a year. | Monitor equipment fabrication and remove any obstacles from fabrication schedule. |
| Delay in critical mechanical equipment freight forwarding. | Equipment delivery may miss winter road period and delay the project by a year. | Appoint specialist logistics consultant to manage overall goods logistics. |
| Delay in receiving sodium cyanide license for procurement. | Sodium cyanide is required to operate the plant. A delay in receiving the license will delay procurement and potentially transport by winter road. | Secure sufficient quantities under supplier license until the next winter road season when Russian paperwork will be in place. |
| Russia closes it borders to supply of goods from Turkey. | Delay in delivery via winter road. | Plan to deliver via another country. |

*table continues...*

| Risk | Impact | Mitigation |
|---|---|---|
| Mishandling of sodium cyanide during transport. | Personnel exposed to cyanide resulting in health issues and possible fatality. | Only let trained personnel transport sodium cyanide. Double contain the sodium cyanide and have an emergency recovery plan in place. |
| Mishandling of sodium cyanide during processing. | Contamination of environment (land and rivers) subject to exposure during a spill. | Only let trained personnel handle sodium cyanide. Train medical personnel on site in sodium cyanide emergency care. Medical evacuation plan. |
| Insufficient water supply due to inadequate season data collection. | Stop operation until water supply is secured. | Conduct full hydrogeological program in the spring. Find alternate winter source of water. |
| There is a possible levy on the deposition of tailings in the TMF by the local authorities that relates to the classification of that material. Discussions with the local authorities are ongoing, however there is a possibility that a charge of $7.88/t of tailings may be payable. | An increase in the operating cost of the mine. | According to Silver Bear, the payment of this levy is negotiable, subject to ongoing test work. Silver Bear has committed to ongoing test work and ongoing discussions with the local authorities. |
| Commencement of construction activities prior to approval of project by Russian Authorities. | Construction activities have already commenced without necessary permits in place. Risk of fines and/or project delays as a result of regulatory enforcement | Complete a detailed compliance assessment and work with regulatory authorities to address gaps. |
| Permits not received as per feasibility study schedule. | Delay in project start-up and commissioning. | Active engagement with regulatory authorities. |
| Monitoring demonstrates that seepage from WRD combined with site contact water requires treatment prior to release to the environment | Water treatment facility during operation and/or post-closure period for elevated metals. | Further waste characterization; water quality monitoring. |
| ESIA and/or Russian regulatory permitting process identify need for additional controls. | Cost of monitoring and mitigating plans including possibility of changes to the project. | Integrate ESIA findings once available; active engagement with regulatory authorities. |

Note: ESIA – environmental and social impact assessment

### 1.16.2 Opportunities

Silver Bear will look to expand their operation by incorporating satellite deposits in the mine license area. The sunk capital cost associated with the infrastructure development for the Project may lower the cut-off grade for subsequent deposits and subsequently the hurdle to entry. The most notable current target is the Mangazeisky North silver deposit.

Tetra Tech believes that it may be possible to identify a more efficient operating point for the (oversized) ball mill to operate during the treatment of relatively soft oxide ore.

## 1.17 RECOMMENDATIONS

Recommendations for the Project are highlighted in Table 1.13. Further details and additional recommendations can be found in Section 26.0.

**Table 1.13 Project Recommendations**

| Area | Recommendations |
|---|---|
| Geology | • adopt an industry standard Geological Database Management System |
| | • complete infill drilling in areas where there is presently insufficient information to predict the grade of mineralization |
| | • conduct a small exploration drilling program in the Mangazeisky South mineralization |
| Mining | • increase material mined during the warmer weather periods, allowing a relaxed operation in the winter months without any interruption in supplying the ore tonnage to the process plant |
| | • implement operational readiness six months before the start of the underground operation to ensure well trained personnel for sub-level open stoping |
| | • adopt an accurate and practical grade control operation with standard sampling and testing protocols with short turnarounds to enable the geology and mining departments to properly plan for the short term mining schedule |
| | • prepare a detailed topography contour map of the open pit, WRD, and the road to the crusher be prepared that can be used in the detail design and scheduling phase during the mining operation |
| Mineral Processing and Metallurgical Testing | • conduct ongoing metallurgical sampling and test work on the oxide ore |
| | • complete a QEMSCAN® mineralogical investigation and silver deportment study for the primary ore |
| | • complete detailed metallurgical test work for the primary ore, including comminution and leach optimization tests along with intensive leach of flotation concentrates with appropriate pre-treatment |
| | • revisit the processing options for the primary ore based on the outcomes of the mineralogical and metallurgical studies and the size of the primary ore reserve |
| | • optimise the ball mill operating duty for soft ore |

*table continues...*

| Area | Recommendations |
|---|---|
| Project Infrastructure | • implement a logistics plan |
| | • prepare a contingency logistics plan |
| | • set up a maintenance camp along the winter road to provide first aid, vehicle breakdown and accident assistance, as well as provision of accommodation and stores for maintenance equipment |
| | • measure fuel quality at every step of supply chain |
| | • complete value engineering study to consider increase cost associated with a future increase in storage against the risk of insufficient supply during the winter road season |
| | • implement standardization on the selection of equipment and material |
| TMF | • investigate methods to minimise the volumes of the surface runoff water reporting to the clarification pond |
| | • model the thermal equilibrium of the dry stack to verify that the dry stack will be frozen with only the top 2-m thick layer being active |
| | • refine the proposed closure plant to consider progressive rehabilitation of the dry stack |
| | • consider the impact of future Russian classification and permitting of the tailings material on the design and associated levy on the placement of tailings material |
| Environmental studies, permitting and social or community impact | • continue to actively engage with government authorities and community stakeholders as part of the Russian review and approval process |
| | • complete a detailed compliance assessment and work with regulatory authorities to address current permit gaps; update project design documentation and include the access road to the mine as part of project permitting |
| | • complete an updated gap assessment against the Equator Principles and IFC Performance Standards to assess the current level of alignment of the Project as defined by the feasibility study |
| | • further engagement with local indigenous communities with regard to land and resources restoration to ensure that social requirements of the IFC Performance Standards are met |
| | • complete further environmental studies to enhance the dataset characterizing the aquatic environment and confirm the source of elevated metals found in the local and regional waterways, including the potential impact of exploration and development activities that have already taken place |
| | • expand the current water balance to include all site-wide sources and to incorporate water quality characterisation; validate model predictions and confirm that environmental mitigation measures are effective and discharge can occur in accordance with anticipated permit conditions without further treatment |
| | • further characterization of the tailings material and the potential for ARD/ML leaching is required; the ARD/ML work completed to date is preliminary |

*table continues...*

| Area | Recommendations |
|---|---|
| | • further study to characterize the predicted quality and quantity of water from the waste rock seepage and surface water runoff collection pond to confirm the assumed acceptability of release without additional management or treatment |
| | • establish more detailed management and monitoring programs to validate that the Project will need to be designed and implemented to support construction, operations, and closure phases |

Note: QEMSCAN® – Quantitative Evaluation of Minerals by Scanning; IFC – International Finance Committee; ARD – acid rock drainage; ML – metal leaching

# 2.0 INTRODUCTION

In August 2016, Silver Bear retained Tetra Tech to complete a feasibility study update of the Mangazeisky Project, located in Far East Russia. Silver Bear is a public limited company incorporated under the *Business Corporations Act* of the Province of Ontario, Canada, on 8th April 2004. Silver Bear is listed on the Toronto Stock Exchange (TSX) under the symbol SBR.

This study focuses on the Vertikaly deposit, and also re-states the current Mineral Resources for the Nizhny Endybal and Mangazeisky North and South deposits.

The effective date of this study is 4th October 2016 and the effective date of the Vertikalny Mineral Resource estimate is 8th July 2016.

The previous work was updated as, shortly after the completion of the original feasibility study, new results from the ongoing geological field program became available which allowed the resource geologist to refine the geological model, to achieve better definition of the mineralised zones and significantly increase the Indicated Mineral Resource estimate. Silver Bear contracted Tetra Tech to complete an updated feasibility-level mine plan and Mineral Reserve estimate for the Mangazeisky Project and to incorporate these changes into the financial model such that an updated feasibility study can be published. The feasibility study update did not change any infrastructure items and the mine production rate was designed to match the process plant capacity.

Tetra Tech worked with additional qualified consulting companies, commissioned by Silver Bear, to complete component studies for the purposes of the feasibility study. Table 2.1 outlines the responsibilities of each company.

**Table 2.1 Consulting Company Responsibilities**

| Company | Responsibility |
|---|---|
| Tetra Tech | overall project management; property description and location; accessibility, climate, local resources; infrastructure and physiography; history; geological setting and mineralization; deposit type; exploration; drilling; sample preparation, analyses and security; data verification; adjacent properties; mineral resource estimates; mineral processing and metallurgical testing; recovery methods, logistical infrastructure; site layout; site access; site geotechnical; structural and architectural design basis; site roads; processing facility infrastructure; site facilities; remote site facilities; waste rock dumps, ore stockpiles and overburden storage area; site water management; waste and sewage; site storage; power supply and distribution; processing and general and administrative capital and operating cost estimates; economic analysis; project execution; mineral reserve estimates; mining methods; mining capital and operating costs |
| ERM | environmental studies, permitting, and social or community impact |
| SRK | mining geotechnical evaluation; TMF; tailings capital and operating costs; hydrology and hydrogeology |

## 2.1 QP SITE VISITS

A summary of the QPs responsible for this report is provided in Table 2.2. The following QPs conducted site visits of the Property:

- Jacques du Toit, CEng, PrEng, MScEng, PMP, visited the site on the 21st July 2014, for one day.
- Robert Davies, BSc (Hons), CGeol, EurGeol, FGS, visited the site from the 23rd to 28th August 2015.
- Laszlo Bodi, P.Eng., visited the site from the 11th to 13th October 2016.
- Houcyne El Idrysy, PhD, CGeol, FGS visited the site on 15th September 2015.

**Table 2.2 Summary of QPs**

| Report Section | | Company | QP |
|---|---|---|---|
| 1.0 | Summary | All | Sign-off by Section |
| 2.0 | Introduction | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 3.0 | Reliance on Other Experts | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS Sabry Abdel Hafez, PhD, PEng. |
| 4.0 | Property Description and Location | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 5.0 | Accessibility, Climate, Local Resources, Infrastructure and Physiography | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 6.0 | History | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 7.0 | Geological Setting and Mineralisation | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 8.0 | Deposit Types | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 9.0 | Exploration | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 10.0 | Drilling | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 11.0 | Sample Preparation, Analyses and Security | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 12.0 | Data Verification | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 13.0 | Mineral Processing and Metallurgical Testing | Tetra Tech | Arunasalam Vathavooran, PhD, CEng, MIMMM |
| 14.0 | Mineral Resource Estimates | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol, FGS |
| 15.0 | Mineral Reserve Estimates | Tetra Tech | Anton von Wielligh, BSc (Hons), PrEng, MSAIMM/ Rene Gharapetian, P.Eng. |
| 16.0 | Mining Methods | Tetra Tech/ SRK | Anton von Wielligh, BSc (Hons), PrEng, MSAIMM/ Rene Gharapetian, P.Eng./ Max Brown, BSc, MSc, CEng, MIMMM |

*table continues...*

| Report Section | | Company | QP |
|---|---|---|---|
| 17.0 | Recovery Methods | Tetra Tech | Arunasalam Vathavooran, PhD, CEng, MIMMM |
| 18.0 | Infrastructure | - | - |
| 18.1 | Overview | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.2 | Logistical Infrastructure | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.3 | Site Layout | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.4 | Site Geotechnical | Tetra Tech | Laszlo Bodi, MSc, CEng, P.Eng. |
| 18.5 | Design Basis | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP<br>Saunjay Duggal,MSc, P.Eng., PE<br>Laszlo Bodi, MSc, CEng, P.Eng. |
| 18.6 | Site Roads | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.7 | Processing Facility | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.8 | Site Facilities | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.9 | Remote Site Facilities | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.10 | Tailings Management Facility | SRK | Krysztof Czajewski, BSc, P.Eng. |
| 18.11 | Waste Rock Dump, Ore Stockpiles and Overburden Storage | Tetra Tech | Laszlo Bodi, MSc, CEng, P.Eng. |
| 18.12 | Site Water Management | Tetra Tech | Guy Roemer, PE |
| 18.13 | Waste and Sewage | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.14 | Site Storage | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.15 | Site Services | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 18.16 | Power Supply and Distribution | Tetra Tech | Damian Hicks, MIEAust, CPEng |
| 19.0 | Market Studies and Contracts | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 20.0 | Environmental Studies, Permitting and Social or Community Impact | - | - |
| 20.1 | Introduction | ERM | Derek Chubb, P.Eng. |
| 20.2 | Permitting Requirements | ERM | Derek Chubb, P.Eng. |
| 20.3 | Environmental and Social Studies | ERM | Derek Chubb, P.Eng. |
| 20.4 | Environmental and Social Impact Assessment, Mitigation and Management Plans | ERM | Derek Chubb, P.Eng. |
| 20.5 | Water and Waste Management | ERM | Derek Chubb, P.Eng. |
| 20.6 | ERM Comments | ERM | Derek Chubb, P.Eng. |
| 20.7 | Closure and Reclamation | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.0 | Capital and Operating Costs | - | - |
| 21.1 | Capital Costs | - | - |
| 21.1.1 | Summary | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |

*table continues...*

| Report Section | Company | QP |
|---|---|---|
| 21.1.2 Basis of Estimate | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.1.3 Direct Costs | Tetra Tech<br>SRK | Jacques du Toit, CEng, PrEng, MScEng, PMP<br>Kris Czajewski, P.Eng. |
| 21.1.4 Indirect Costs | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.1.5 Qualifications, Assumptions and Exclusions | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.2 Operating Costs | - | - |
| 21.2.1 Summary | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.2.2 Basis of Estimate | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 21.2.3 Mining | Tetra Tech | Anton von Wielligh, BSc (Hons), PrEng, MSAIMM/<br>Rene Gharapetian, P.Eng. |
| 21.2.4 Processing | Tetra Tech | Arunasalam Vathavooran, PhD, CEng, MIMMM |
| 21.2.5 Tailings Management Facility | SRK | Krysztof Czajewski, BSc, P.Eng. |
| 21.2.5 General and Administrative | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 22.0 Economic Analysis | Tetra Tech | Sabry Abdel Hafez, PhD, P.Eng. |
| 23.0 Adjacent Properties | Tetra Tech | Robert Davies, BSc (Hons), CGeol, EurGeol., FGS |
| 24.0 Other Relevant Data and Information | - | - |
| 24.1 Project Execution Plan | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 24.2 Risks and Opportunities | Tetra Tech | Jacques du Toit, CEng, PrEng, MScEng, PMP |
| 24.3 Hydrogeology and Water Supply | SRK | Houcyne El Idrysy, PhD, CGeol, FGS |
| 25.0 Interpretation and Conclusions | All | Sign-off by Section |
| 26.0 Recommendations | All | Sign-off by Section |
| 27.0 References | All | Sign-off by Section |
| 28.0 Certificates of Qualified Person | All | Sign-off by Section |

## 2.2 SOURCES OF INFORMATION

All sources of information for this study are located in Section 27.0.

## 2.3 UNITS OF MEASUREMENT AND CURRENCY

All units of measurement used in this technical report are in metric.

All currency is in US Dollars, unless otherwise noted.

# 3.0 RELIANCE ON OTHER EXPERTS

## 3.1 GEOLOGICAL RELIANCE

Tetra Tech has reviewed and analysed data provided by Silver Bear, its consultants and previous operators of the Property, and has drawn its own conclusions, augmented by its direct field examination.

While exercising all reasonable diligence in checking, confirming, and testing, Tetra Tech has relied upon Silver Bear's presentation of the data for the Project in formulating its opinion and estimates.

The various agreements under which Silver Bear holds title to the mineral lands for the Project have not been reviewed by Tetra Tech, and Tetra Tech offers no opinion as to the validity of the mineral title claimed. Tetra Tech is relying on legal opinions regarding Property title prepared by experts who are not QPs as defined by NI 43-101. A legal title opinion was authored by Ivan A. Trifonov, Managing Partner of Squire, Sanders & Dempsey (Moscow) L.L.C. in Appendix 2 of the 2004 Technical Report by Roscoe Postle Associates Inc. (RPA 2004). A description of the Property and ownership is provided for general information purposes only in Section 4.0.

The description of geology, mineralisation, and exploration methodology used in this report are based on direct field examination, and on data available in published and unpublished reports supplied by Silver Bear. In turn, Silver Bear has relied on various reports and data supplied by state organisations and others that have previously conducted exploration on the Property. The information provided to Silver Bear was supplied by reputable state organisations and Tetra Tech has no reason to doubt its validity.

## 3.2 ECONOMIC RELIANCE

Tetra Tech relied on Graham Hill, Chief Executive Officer of Silver Bear, to provide the following inputs used in the economic analysis section:

- royalties applicable to the Project
- smelting and refining quotation
- silver off-site transportation and insurance costs.

Tetra Tech relied on PwC concerning tax matters relevant to this report. The reliance is based on a letter to Silver Bear titled "Assistance with the calculation and review of the Russian income and mining tax portion (the 'tax section') of the Feasibility Study Model (the 'Model') in connection with the NI 43-101 Technical Report (the 'Report') for the Mangazeisky project (the 'Project') prepared by an external consultant engaged by Silver Bear Resources Inc. ('Silver Bear' or the 'Company' or the 'Client')" and dated 3rd October 2016.

# 4.0 PROPERTY DESCRIPTION AND LOCATION

The Property is defined by the mineral rights to a single mining license, and is 100% held by Prognoz, a private Russian closed-joint stock company based in Yakutsk. Prognoz is a 100% held subsidiary of Silver Bear.

## 4.1 LOCATION

The Property is located:

- at approximately 590,960 m east and 7,234,750 m north (Zone 36J; World Geodetic System (WGS 84)
- at approximately 65°40' south and 130°07' east; in central Sakha Republic (Yakutia), Kubyaysky District of Russia
- approximately 400 km north of Yakutsk, capital city of the Sakha Republic
- approximately 300 km southwest of Batagai in northern Sakha Republic
- approximately 230 km north of Sangary, a river port on the right bank of the Lena River, and administrative centre for the Kubyaysky District.

The Property is situated as shown in Figure 4.1.

**Figure 4.1 Property Location Map**

Source: Silver Bear

## 4.2 DESCRIPTION

Silver Bear holds the mineral rights to the Property through its 100% interest in Prognoz. Silver Bear purchased Prognoz in 2004 from the National Resource Company.

The Property is located in the north of Kobyaysky District, in central Sakha Republic (Yakutia), and is comprised of one mining licence within a larger exploration licence. The mining license, number YaKU 03626 BE, covers the entire Vertikalny silver deposit over an area of 13.55 km$^2$. The coordinates of the mining license are shown in Table 4.1.

**Table 4.1 Mining License Coordinates**

| Mining License YaKU 03626 BE | | |
|---|---|---|
| Corner No. | Northing Coordinate | Easting Coordinate |
| 1 | 65°41'15.917" | 130°01'55.380" |
| 2 | 65°41'41.938" | 130°03'23.150" |
| 3 | 65°41'37.066" | 130°04'59.859" |
| 4 | 65°41'20.210" | 130°06'27.196" |
| 5 | 65°40'08.102" | 130°08'20.361" |
| 6 | 65°39'44.803" | 130°08'11.742" |
| 7 | 65°39'40.272" | 130°07'17.802" |
| 8 | 65°39'46.221" | 130°05'22.190" |
| 9 | 65°39'54.675" | 130°03'29.389" |
| 10 | 65°40'11.350" | 130°01'57.673" |
| 11 | 65°40'46.388" | 130°01'42.001" |

The mining license is situated in the central west portion of the larger Endybal exploration license (also known as the Mangazeisky exploration license), number YaKU 12692 BP, and covers several other exploration targets and silver deposits over an area of 570 km$^2$. The coordinates of the exploration licence are shown in Table 4.2.

**Table 4.2 Exploration License Coordinates**

| Exploration License YaKU 12692 BP | | |
|---|---|---|
| Corner No. | Northing Coordinate | Easting Coordinate |
| 1 | 65°49'35" | 130°00'00" |
| 2 | 65°49'35" | 130°19'20" |
| 3 | 65°29'00" | 130°22'00" |
| 4 | 65°29'00" | 130°00'00" |

## 4.3 HISTORY OF PROPERTY ACQUISITION

On 21st October 2004, Silver Bear completed an acquisition of all of the outstanding shares of Prognoz. Pursuant to the transaction, Silver Bear acquired 100% of the issued and outstanding common shares of Prognoz for RUB10,000,000 or CAD331,000 and assumed certain bank indebtedness and other liabilities of Prognoz. The parties to the transaction agreed that the value of the exploration licences held by Prognoz closely approximated the indebtedness assumed and accordingly, a value of RUB20,585,221 or CAD890,310 was attributed to the licences. Tetra Tech is not aware of any liability in the form of royalties or other financial encumbrances, but these may be applicable.

The exploration licence YaKU 12692 BP was granted to Prognoz on 24th September 2004 by the Federal Subsoil Resources Management Agency (ROSNEDRA), and was

valid for an initial term of five years. On 18th February 2009, the exploration licence was extended by ROSNEDRA to 31st December 2011. Another extension was subsequently granted for one year until 31st December 2012. On 27th December 2012, a third extension was granted for four years until 31st December 2016.

The exploration licences give the recipient the authority to use the subsoil for the purposes of geological investigation within the licence area, for exploration, and appraisal of the gold and silver deposits. The licence area has the status of a "geological allotment" with the preliminary borders outlined and an unlimited licenced depth for investigation. According to the English translations of the exploration licences, there are no specially protected natural territories within the limits of the licence.

In September 2013, Silver Bear received its mining licence YaKU 03626 BE for the Vertikalny deposit. The term of the licence is approximately 20 years (to 2033). The licence requirements include:

- completion of 15,000 m of drilling and 15,000 $m^3$ of trenching by or before December 2017
- initiation of drilling and trenching no later than March 2015
- mine must be operational within the next nine years (2023), inclusive of permitting and report approvals
- mine output must be greater than 180,000 t/a by the year 2023.

A summary of all of the existing licence information is detailed in Table 4.3.

**Table 4.3 Property Mineral Licences**

| Licence Name | Licence ID | Type | Area ($km^2$) | Issue Date | Expiry Date | Annual Fees (RUB) |
|---|---|---|---|---|---|---|
| Endybal Area (Mangazeisky) | YaKU 12692 BP | Geological Allotment | 570.00 | 28th September 2004 | 31st December 2016 | 153,900 |
| Vertikalny Deposit | YaKU 03626 BE | Licence to Use Subsoil | 13.55 | 31st August 2013 | 1st September 2033 | 110,771 |

## 4.4 SURFACE RIGHTS

Silver Bear does not hold any surface rights on the Property, but has access to the Property for the purposes of mineral exploration. Construction activities have commenced on the Property but are not supported by having all of the necessary permits in place. Silver Bear acknowledges this is a risk to the Project and is working with the regulatory authorities to obtain the necessary construction and operations permits.

## 4.5 ENVIRONMENTAL LIABILITIES

According to the licence granted by ROSNEDRA, the main environmental requirements during exploration activities for the exploration licence are as follows:

- observance of the established requirements for protection of the environment and subsoil
- performance of necessary measures to reduce or prevent pollution caused by the execution of the exploratory work
- prevention of water facility pollution and clogging and observance of the regime of water protection zones
- reclamation of land disturbed during exploratory work, restoring it to a state suitable for further use and in compliance with landscape and recreational specifics of the territory
- timely payment of compensation for damages caused to hunting, agriculture, fisheries, and forestry
- coordination with and approval by the Administration for Subsoil Use in the Republic of Sakha-Yakutia (YAKUTNEDRA) for the terms and types of work to be carried out within the water protection zones.

Preliminary laboratory tests indicate that concentrations of minerals in some surface water and sediment samples exceed local regulatory standards. These elevated concentrations are attributed to natural weathering processes across the Project affecting regional watersheds and to exploration activities in local waterways near the Vertikalny deposit area. The feasibility study does not include an allowance to remediate any historical impacts that may be caused to date by Project activities.

# 5.0 ACCESSIBILITY, CLIMATE, INFRASTRUCTURE, LOCAL RESOURCES AND PHYSIOGRAPHY

The Property is located in the Kobyask district within the Republic of Sakha (Yakutia) of the Russian Federation. Yakutia covers an area of 3.1 Mkm$^2$, makes up one fifth of Russia's landmass, and has a population of approximately 1.0 million people. The region is rich in natural resources and 80% of its industrial production originates from the non-ferrous metals industry (diamonds, gold, tin) and antimony and fossil fuel energy (coal, gas, and oil). Over 10% of the available work force of 0.5 million people are involved in mining.

The major population centre for the region of Yakutsk has approximately 300,000 inhabitants. Yakutsk is located approximately 400 km south of the Property.

Yakutia recognises the present and long-term predicted demand for mineral resources in the region, and is implementing a strategic plan for the social and economic development of the region ("Scheme of Complex Development of Productive Forces, Transport and Power Industry of the Sakha Republic [Yakutia] by 2020"), which is supported by the Russian Federation Government. It is hoped that the Project will create new transportation corridors, increase export opportunities, and create employment and subsequent population inflow. It is also hoped that the Project will increase national security and assist integration with the Asia-Pacific regions. The majority of the infrastructure improvements will not have a direct impact on the Project especially in its early stages. Opening of supply lines etc. will have a positive impact in terms of supply of consumables and labour.

## 5.1 ACCESSIBILITY

The Property is only accessible from Yakutsk by air, either by fixed wing aircraft or by helicopter. There is an airstrip on the Property, at the confluence of the Endybal and Arkachan Rivers, approximately 10 km from the base camp. There are several charter companies based in and around Yakutsk for both types of aircraft. A flight by AN-2 is typically two hours.

The Property may also be accessed via Batagai, located approximately 300 km northeast of the Property. There are regular scheduled flights to Batagai as well as aircraft available for charter.

There is also a winter road that is open for several months during the winter for transport of all freight and supplies to the Property.

## 5.2 CLIMATE

The climate of northeast Russia is Continental subarctic to Tundra Climate zones (Dfd to ET; Köppen climate classification), and is characterized extreme cold dry winters and cool summer seasons. There is no climatic station at the Project site, but data is available from Verhojansk (National Oceanic and Atmospheric Administration (NOAA) Station ID RA24266; 67°33' north, 133°23' east, 137 m) and Yakutsk (NOAA Station; ID RA24959; 62°01' north, 129°43' east, 101 m).

The annual precipitation averages 200 mm with the majority occurring as rain during the summer months. Average temperatures range from +25°C in July to −40°C in December and January; although during the winter the temperatures can decrease to a low of −65°C for short periods. Snow cover is formed around the end of September and will have usually melted by the second half of May. The thickness of the snow varies from 40 to 50 cm. The rivers are usually ice-bound at the end of September and spring break-up is completed by the end of May. The region experiences light winds throughout the year.

The area has a permafrost layer of 300 to 400 m in thickness, or more.

Exploration activities may take place most of the year; however, the field season typically extends from April/May to September/October.

## 5.3 INFRASTRUCTURE

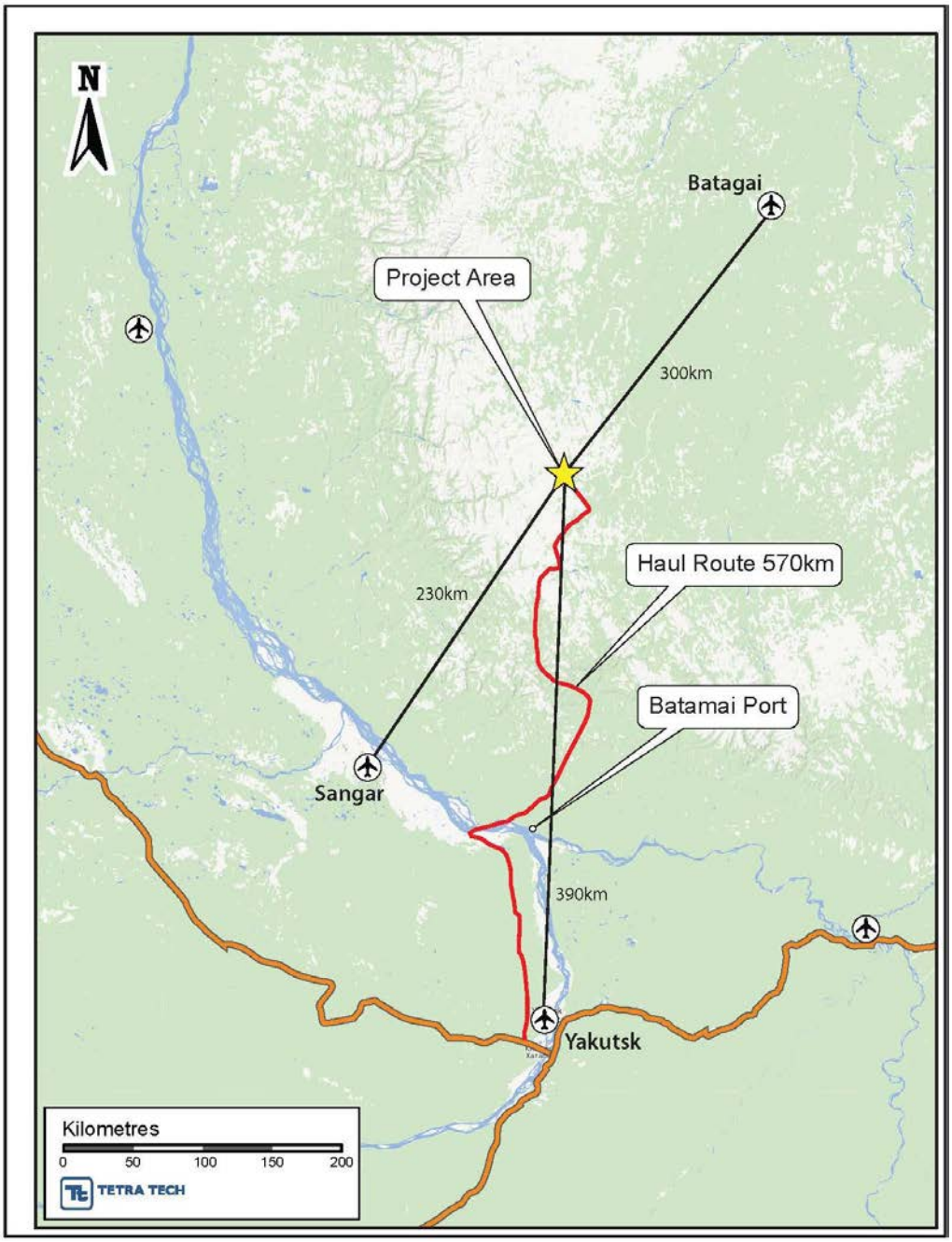
### 5.3.1 ROADS

Yakutia has a poorly developed road network and only 8% of the republic's territory is accessible all-year-round; the remaining 92% is seasonally accessible. Through rapid expansion it is hoped that the road infrastructure can be developed such that 91.5% of the population will have access to the republican centre and that 47.5% of the republic’s territory will be provided by year-round motorways. Currently over 70% of passenger traffic is by air.

The Project area is isolated and can be accessed by a winter road that is usable from mid-January until mid-April, depending on the depth of snow fall. All-terrain vehicles (ATVs) are used for transporting workers and materials to site. The vehicles have a capacity of 7 t and a round trip from Yakutsk to the Property takes six days. Outside of this three month window, the roads are impassable due to surface thaw of the permafrost and subsequent boggy conditions and swollen river crossings.

The haul route currently used is shown in Figure 5.1. From Yakutsk to the Lena River crossing, there is a year-round road (approximately 200 km). The Lena River is navigable from June until September and has a barge capacity of up to 3,000 t at Batagai, as well as at Sangar. During the winter haulage season, the Lena River may be driven on by trucks up to 20 t. An additional 370 km along the winter road makes a total haulage distance of 570 km.

**Figure 5.1 Airports and Current Haul Route**




Source: Tetra Tech

Batagai is the administration centre for the Verkhoyanskiy district with a population of approximately 2,000 inhabitants and is situated approximately 280 km to the northeast of the Property. The closest accommodation is located in this town, which has two hotels and restaurants.

Batagai has a river port, along with aviation and transportation companies, a telegraph, and post office. There is an all-weather dirt road between the villages of

Batagai and Tokuma, and from Tokuma there is a link to the Property via a winter road, which is open for only a short period.

The closest village to the Property is Sebyan-Kuel which is located approximately 50 km south. The village of Sangar, located 240 km southwest of the Project, is the administrative centre for the district of Kobyask Ulas, which includes the area encompassed by the Project.

### 5.3.2 Air Transport

During most of the year the Property is accessible primarily by helicopter or light fixed wing aircraft from Yakutsk, Batagai, or Sangar. From Yakutsk, the weather may interfere with flight schedules due to the intervening Verkhoyanskiy mountain range and delays of days and occasionally weeks are not uncommon. From Batagai, the helicopter service is more frequent, but delays due to weather conditions may occur. At the Mangazeisky exploration camp there is a helicopter pad, along with a small airstrip upon which to land small planes. The airstrip was extended to 800 m in 2009 and there is the possibility to extend further to around 1,200 m.

Currently, AN-2 and AN-3 fixed wing aircraft are being used for small loads (800 to 900 kg); MI-8 MTV and MI-26 helicopters are available for heavier loads (up to 1,800 kg).

### 5.3.3 Rail and Ports

The Berkakit-Tommot-Yakutsk rail link is reportedly near completion. The rail head will be located on the east side of the River Lena; it is not known if a bridge is planned. This spur will link Yakutsk to the Trans-Siberian, Amur-Yakutia Railroad and the Northern Sea Route. Journey times will be significantly reduced.

Further rail links are planned that will eventually connect Yakutsk to Magadan and the Sea of Okhotsk.

The River Lena is navigable from April until late September. The river ports of Yakutsk, Batamai, and Sangar may be used to reduce the haulage distance to site by approximately 200 km.

### 5.3.4 Power

There is no access to the main power grid on the Property. The Kobyask district is located in the decentralised power supply zone, and has a power generating capacity of 16 MW coming from 12 diesel generating sites. The nearest power generator set to the Project site is at Sebyan-Kuel (375 kW).

The main power supply company for Yakutia is Sakha Energy. The current power supply system incorporates three isolated power networks; the southern, western, and eastern regions and a decentralised region. Power is generated by both thermal and hydro-electric methods in the main regions. The primary source of electrical power in the decentralised region is diesel generation and alternative sources of energy such as wind power are being introduced.

By 2020, the electrical generating capacity of Yakutia will be supplemented with a further 8,500 MW from seven new power stations. The distribution network will be expanded to join the current isolated regions and connect to the unified power grid of Central and Western Russia.

## 5.4 LOCAL RESOURCES

The Property is relatively isolated with limited local resources. The base camp, Hogan Camp, is comprised of one to two room cabins, huts and accommodation containers. There are several permanent structures for kitchen, bath, and offices. There are also buildings for core logging and sampling, sample preparation and sample storage, as well as sheltered core box storage.

Potential water sources include the Arkachan River, located 10 km from the Project, and the Endybal, Sirelendge, Fedor-Yuryage, and Mangazeisky creeks, which flow through the licence area. Water resources may also become available from underground exploration and development. Silver Bear is working with regulatory authorities to obtain relevant permitting for the use of water resources.

## 5.5 PHYSIOGRAPHY

The Property lies in a mountainous region with elevations ranging from 800 to 1,400 masl. The main ridges have steep slopes (25 to 30° and rounded crests that are 200 to 500 m above the valley floors).

The vegetation surrounding the Property is composed of primarily aspen, birch and fir trees in the lower parts of the valleys with generally only grass and wildflowers at higher elevations. There are also widespread lichens and mosses. The region is well known for species such as bear, ermine, wolverine, fox, deer, elk, squirrel, and wolf. There is an abundance of fresh water fish in the streams and lakes, including grayling, lenok, pickerel, taimen, and perch.

# 6.0 HISTORY

## 6.1 EXPLORATION HISTORY

### 6.1.1 GENERAL EXPLORATION HISTORY TO 2004

Discovery of the mineralisation within the Property is attributed to the Russian Cossacks in 1764. Intermittent exploration by individuals continued until the formation of the Soviet Union in 1917. Upon nationalisation of all assets, exploration and mining became the responsibility of various government departments or agencies. Sporadic exploration was then undertaken during the 1930s and 1940s.

During 1952 and 1953, work focused on two previously identified showings identified as the Mikhailovsky and Kuzminsky zones, which are located 7.5 km and 10 km to the north of Vertikalny, respectively (Figure 7.4 presents a map of the explored mineralisation within the licence area). This work included geological mapping (1:50,000), trenching with systematic mapping and sampling, and the establishment of two short adits (32 m) beneath the trenches. Work also included a topographic survey (1:2,000, 3 $km^2$) and an induced polarisation (IP) survey (1:5,000, 1.7 $km^2$). By 1960, the exploration work completed in the licence area had identified more than 160 anomalies, within a north-south trend up to 20 km in length. This trend is 2 km wide in the north (Nuektame River) and up to 4.5 to 5.0 km wide in the south (Endybal River).

In 1989, systematic prospecting and exploration resumed, and has continued to this day.

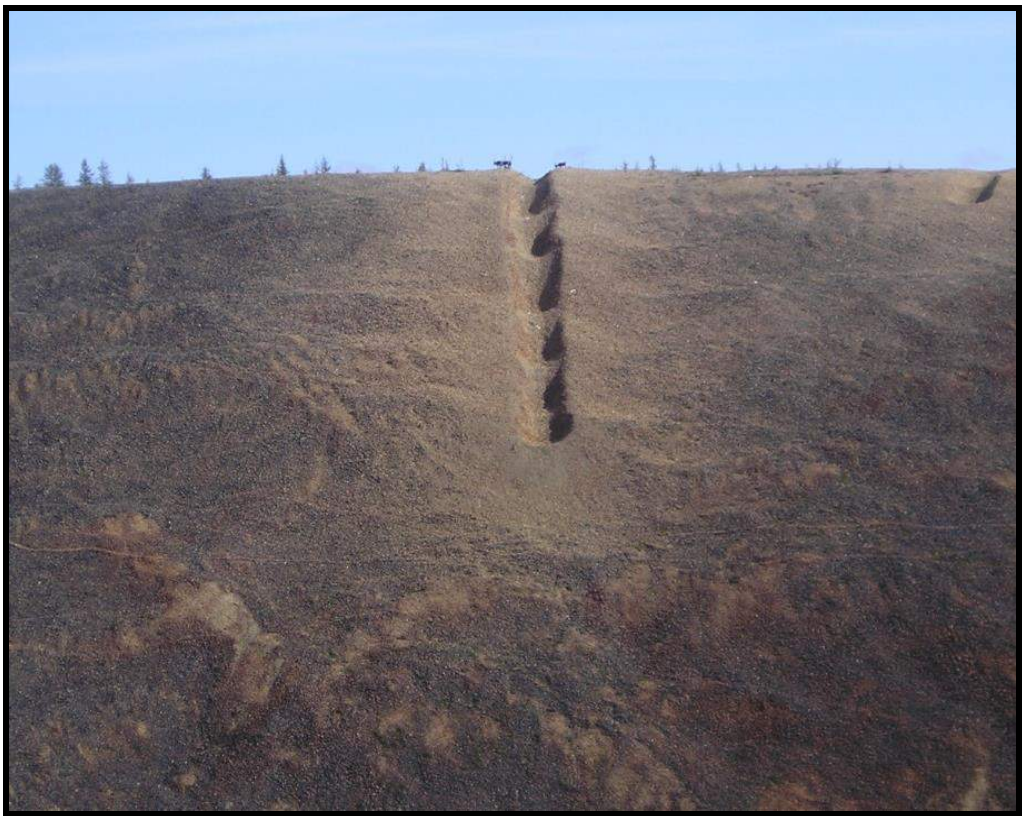
From 1991 to 2003 JSC Yangeologia completed 151,452 $m^3$ of trenching, 10.2 line km of magnetic surveys, detailed geological mapping, soil geochemical surveys, and 10 diamond drillholes totalling 1,303 m. This exploration work covered more than 15 principal vein systems.

From 1989, exploration was primarily located within the Vasilievsky, Sterznhevoy, and Nizhne-Endybalsky mineralised zones, bringing the total number of discretely mineralised structures containing potentially economic grades to more than 30.

Figure 6.1 shows an example of a historical trench on the Property.

Prognoz acquired the Mangazeisky exploration licence in September 2004. On 21st October 2004, Silver Bear acquired 100% of Prognoz by purchasing the company from National Resource Company.

**Figure 6.1 Historical Trenches on the Property; Porphyrovy Zone**



Source: Silver Bear

### 6.1.2 METALLURGICAL TEST WORK AND RECOVERABILITY

Initial metallurgical results were summarised in a report by Western Services (2004). The Western Services (2004) report describes metallurgical test work that was conducted on two samples from the Property. One sample, from the Vasilievsky vein, was composed of un-oxidised primary silver mineralisation, and contained minor components of lead, zinc, and copper along with minor stibnite. The silver was primarily concentrated within sulphosalts and present as native silver.

Single step flotation tests resulted in recovering 95% of the contained silver into a concentrate. The concentrate grade was 48 kg/t silver. Cyanidation of the flotation product recovered 99.1% silver from the concentrate. The total recovery was projected to be in the order of 94% for the material contained in the southern block of Vasilievsky.

A gravitational recovery circuit was also investigated, in which 57% silver was recovered into a concentrate with an average grade of 20.15 kg/t silver. Cyanidation of the gravity concentrate recovered 99.2% silver from the concentrate. The total recovery for this process option was 57%.

The second metallurgical sample collected was from the silver-lead Granichny mineralised zone. It consisted of partially oxidised mineralisation composed mainly of galena, sphalerite, and anglesite (0.1 to 2.0 to 3.0 mm in size). The silver occurred as freibergite, pyrargyrite, and argentite (0.02 to 0.50 mm in size) as well as extremely

fine-grained native silver. The second sample weighed 17.1 kg with an average grade of 320 g/t silver, 12% lead, and 1.4% zinc.

Based on the metallurgical test work, a single stage flotation circuit recovered 80.9% lead and 89.2% silver into a concentrate. Cyanidation results for the concentrate were not reported.

In 2008, Silver Bear collected two bulk samples from the Vertikalny vein. The samples were collected from the mineralisation intersected by surface trenching. The samples were submitted to the Federal State Unitary Enterprise Central Institute of Science Research and Geological Surveying of Base and Precious Metals (TSNIGRI) for metallurgical analysis. The results of this work are described in the 2009 technical report (Wardrop 2009a) and reproduced in Section 13.0 for convenience.

## 6.2 HISTORICAL RESOURCE ESTIMATES

### 6.2.1 HISTORICAL NON-COMPLIANT RESOURCE ESTIMATES

The Property has historical Mineral Reserve and Resource estimates on numerous deposits prepared according to the Russian classification system. Further clarification of the Russian classification system can be found in Ministry of Natural Resources of the Russian Federation (MNRRF) Order of 11th December 2006 No. 278, Classification Approval and Predicted Resources Solid Minerals (MNRRF 2006).

The historical Mineral Reserve estimate was reviewed by JSC Yangeologia (2000) and is based entirely on chip samples from within trenches and outcrop exposures within the river banks. Most of the silver assays were established using the gamma-activation method with external control by fire assay. Lead, zinc, tin, antimony, and copper were determined by using the x-ray radiometric method. The reported methodology (Young 2004) is outlined in the following paragraphs.

An average silver composite grade within each trench was calculated using a length weighted averaging for the intervals assaying in excess of 150 g/t silver.

The composited trench results were plotted in plan view, and the limits of the mineralisation within and between the trenches were linked together. Based on the trenches contained within the mineralised intercept outline, an average mineralised thickness was determined. The average contained grade of the mineralisation was calculated for all mineralised trenches and was also completed on a length weighted basis.

Vertical longitudinal projections were then constructed for each zone. The projection distance downward was 100 m below the surface for almost all of the mineralised zones. The depth of the projected trench values from the surface was based on the methodologies employed at the nearby Prognoz silver project, which has similar drill results as well as a similar geological genesis, mineralisation type, and overall character.

The projected area was multiplied by the weighted average thickness to estimate a mineralised volume. This volume was multiplied by one of several specific gravity

values, which were established from 56 samples collected from the major mineralised zones. These specific gravity values were determined by the Yakutsk Nuclear Physics Laboratory in 1992.

The tonnage, average metal grades and thickness for all discrete mineralised zones or subzones were then summarised into a tabular format for the final reporting of the estimated inventory. This mineralisation is contained the part of the deposit located nearest to the surface and was classified in the P1 category according to the Russian reserve/resource classification system. This classification was selected as there was very little sub-surface sampling (drilling or underground exploration) available to establish the down dip continuity of the mineralisation.

The mineralisation located at greater depth was then compiled and categorised in the P2 class. This material was derived by projecting the mineralisation approximately another 100 m below the P1 lower datum limit. Typically, this resulted in a doubling of the total tonnage over that represented by the P1 material

A total of 36 mineralised structures have been identified as including P1 and/or P2 Russian classified “reserves”. Table 6.1 summarises the distribution of the historical Russian “reserves” by mineralised zone with the top 15 zones reported individually and the remaining zones combined.

**Table 6.1 Summary of the Historical Russian Inventory by Mineralised Zone for the Property**

| Mineralised Zone | Tonnes (kt) | Horizontal Width (m) | Average Grade | | | | Contained Metal | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Ag (g/t) | Au (g/t) | Pb (%) | Zn (%) | Ag (t) | Au (t) | Pb (t) | Zn (t) |
| Vasilievsky | 9,076 | 2.00 | 1,944 | - | 7.89 | 0.31 | 17,646 | - | 716,049 | 28,265 |
| Sterznhevoy | 153 | 0.90 | 2,652 | 0.80 | 0.31 | 0.10 | 405 | 0.12 | 473 | 153 |
| Mikhailovsky | 233 | 0.45 | 2,384 | - | 24.64 | 1.19 | 555 | - | 57,345 | 2,769 |
| Kuzminsky | 61 | 0.22 | 1,492 | - | 13.53 | 0.47 | 91 | - | 8,285 | 286 |
| Burnoe | 268 | 0.67 | 2,756 | - | 30.10 | 1.00 | 739 | - | 80,668 | 2,680 |
| Mukhalkansky | 1,048 | 0.00 | 1,509 | - | 19.58 | 1.05 | 1,581 | - | 205,205 | 11,039 |
| Semenovsky | 503 | 0.6 | 2,278 | - | 24.00 | 1.20 | 1,145 | - | 120,600 | 6,030 |
| Zabyty | 484 | 0.61 | 1,299 | - | 14.72 | 6.45 | 629 | - | 71,228 | 31,202 |
| Granichny | 209 | 1.25 | 954 | - | 11.02 | 1.38 | 200 | - | 23,073 | 2,889 |
| Vostochny | 80 | 0.95 | 1,272 | - | 12.80 | 0.27 | 101 | - | 10,184 | 215 |
| Nizhny Endybal | 2,020 | 3.00 | 874 | - | 3.06 | 1.38 | 1,766 | - | 61,868 | 27,897 |
| Privet | 115 | 1.28 | 994 | 0.50 | 4.00 | 0.83 | 114 | 0.49 | 4,608 | 956 |
| Mysovoe | 194 | 0.29 | 2,435 | - | 36.08 | 0.70 | 472 | - | 70,000 | 1,358 |
| Bezymyanny | 661 | 0.76 | 1,965 | - | 0.51 | 0.17 | 1,300 | - | 3,367 | 1,143 |
| Vertikalny | 322 | 1.10 | 1,529 | - | 5.90 | 6.70 | 493 | - | 18,977 | 21,550 |
| Olgina | 121 | 0.62 | 2,640 | - | 1.65 | 0.68 | 318 | - | 1,988 | 817 |
| All Other Mineralisation | 1,216 | 1.00 | 2,281 | 0.15 | 15.20 | 1.60 | 2,774 | 0.22 | 184,840 | 19,457 |
| Total/Weighted Average | 16,764 | - | 1,809 | 0.24 | 9.78 | 0.95 | 30,329 | 1 | 1,638,758 | 158,706 |

Source: Young (2004)

Table 6.2 summarises the historical Russian inventory by category according to the Russian classification system.

**Table 6.2 Summary of the Historical Russian P1 and P2 Inventory for the Property**

| Russian Reserve Category | Tonnes (kt) | Average Width (m) | Average Grade | | | Contained Metal | | |
|---|---|---|---|---|---|---|---|---|
| | | | Ag (g/t) | Pb (%) | Zn (%) | Ag (t) | Pb (t) | Zn (t) |
| Total P1 Reserves | 7,881 | 1.34 | 1,717 | 8.28 | 0.80 | 13,529 | 652,524 | 62,707 |
| Total P2 Reserves | 8,883 | 0.93 | 1,891 | 11.10 | 1.08 | 16,799 | 986,233 | 95,999 |
| **Total** | **16,764** | **1.09** | **1,809** | **9.78** | **0.95** | **30,328** | **1,638,757** | **158,706** |

Source: Young (2004)

All inventory calculated in 2000 were reviewed by JSC Yangeologia, a federal geological agency within Russia.

Historical C class inventory have also been estimated for the Property using the Russian classification system (see Table 6.3).

**Table 6.3 Historical Resources for the Property**

| Mineralised Zone | Russian Category | Contained Ag (Moz) | Au Grade (g/t) |
|---|---|---|---|
| Vertikalny | C1 | 14.17 | 729 |
| Vertikalny | C2 | 22.72 | 588 |
| Mangazeisky North | C2 | 10.86 | 1,656 |

The C1 and C2 inventories are based on a Russian TEO Conditsy Report (TEO) (Russian prefeasibility study) of December 2011 by Oreall Engineering and confirmed by Russian State Commission on Mineral Reserves (GKZ) in Protocol document No. 2754 (GKZ ROSNEDRA) of 13th April 2012.

The cut-off grade used for the C1 and C2 material was 75 g/t silver. Based on protocol document No. 2754, Silver Bear received its Certificate of First Discovery from ROSNEDRA on 2nd August 2012. The C2 Resource (Mangazeisky North) was based on a 2007 JSC Yangeologia annual property report filing.

The historical Russian Reserve and Resource estimates do not conform to the CIM Standards and Definitions for Resource Estimates. A QP has not carried out sufficient work to verify the historical estimates as current Mineral Reserves and Mineral Resources and therefore, Silver Bear is treating the numbers as historical only.

### 6.2.2 Historic NI 43-101 Compliant Resource Estimates

In March 2009, Tetra Tech (formerly Wardrop Engineering Inc.) published an initial NI 43-101 Mineral Resource estimate for the Vertikalny structure (Wardrop 2009a) that was later revised in December 2009 (Wardrop 2009b). The Mineral Resource was further updated in the September 2011 PEA (Wardrop 2011) and February 2015 (Tetra Tech 2015a).

## 6.3 HISTORICAL PRODUCTION

There has been no historical production on the Property. Due to the remote location and lack of infrastructure there has been very little mining in this region.

# 7.0 GEOLOGICAL SETTING AND MINERALIZATION

## 7.1 REGIONAL GEOLOGY

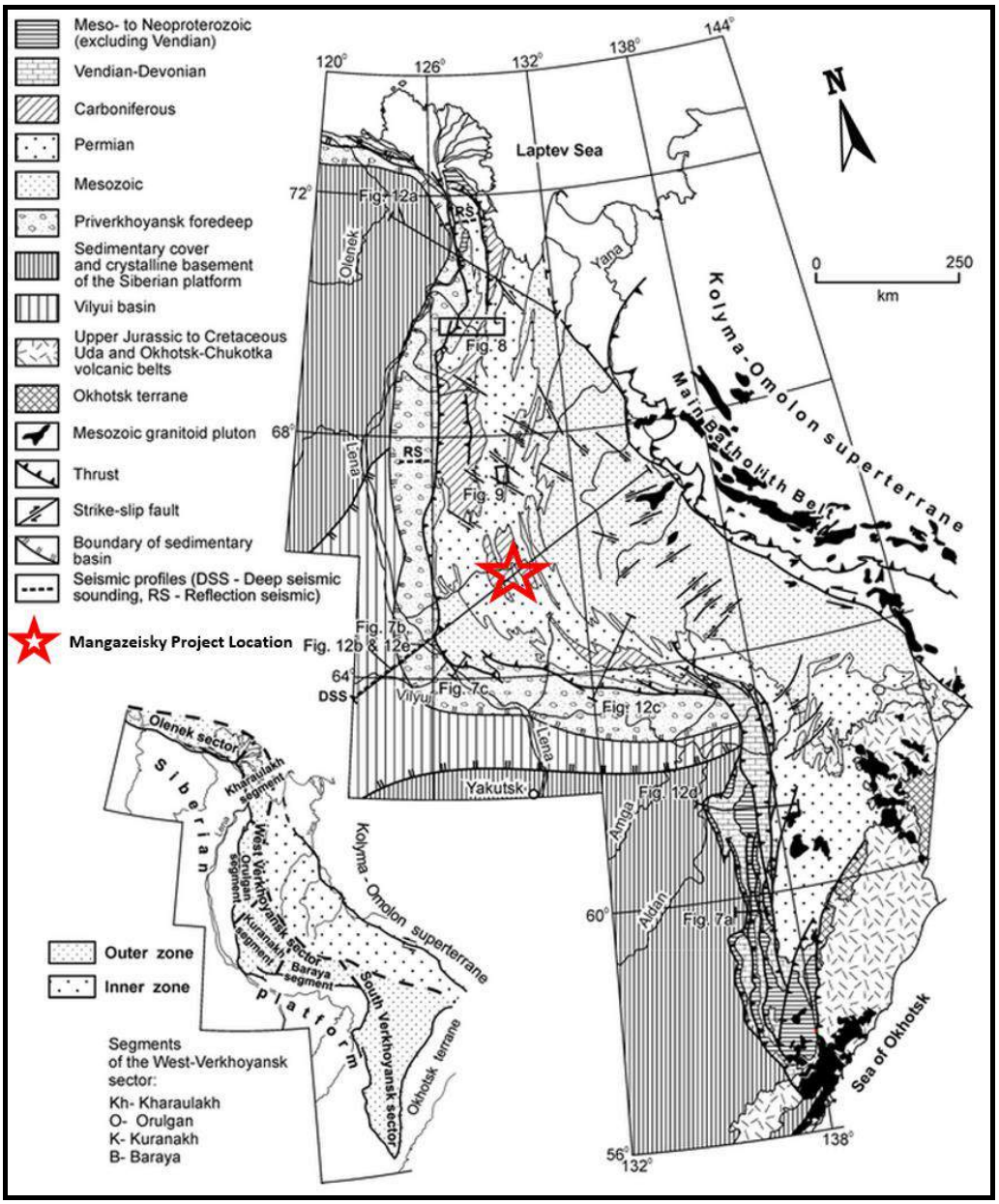
The Property is located within the Verkhoyansk mobile belt of north-eastern Yakutia. The fold-and-thrust belt forms part of a major orogenic system separating the Siberian North Asian Craton to the west from the immense expanse of accreted terranes that form most of the Russian Far East.

The belt extends for 2,000 km from the Laptev Sea to the Sea of Okhotsk. It is comprised of a greater than 7-km thick sequence of Late Precambrian to Triassic rocks deposited along the Palaeo-Pacific margin of the Siberian Craton, which developed because of rifting events during the Late Precambrian period and again during the Late Devonian to Early Mississippian periods.

Deformation during the Late Jurassic to Early Cretaceous occurred with low-grade metamorphism in the internal parts of the belt and the emplacement of high-level granitic bodies. Strike-slip faulting occurred during the Tertiary period.

The central part of the belt is dominantly comprised of a thick, monotonous succession of Carboniferous and Permian turbidites that are metamorphosed to lower greenschist facies. Granodiorite and granite plutons have intruded the core of the belt and are associated with extensive gold-bearing quartz vein systems.

**Figure 7.1 Regional Geology of the Property**




Source: Miller et al. (2002)

## 7.2 PROPERTY GEOLOGY

The mineral occurrences on the Property are located in the interfluve of the Nuektame and Arkachan rivers and ranges from the mid-channel of the Muhalkan River to the mouth of the Mysovoi Stream. The mineral deposits are confined to the eastern wing of the Kuranakhsky anticlinorium and are situated within the contours of the Endybal anticline.

Higher order asymmetric anticlinal and synclinal folds that are 2 to 20 km in length complicate the hinge portion of the Endybal anticline. The Mukhalkansky anticline with a north-northwest strike (340°) and the Mangazeisky syncline, which are

adjacent on the western side, complicate the eastern wing of the Endybal anticline. The dip of the rocks of the Endybal anticline in the area of the Mangazeisky deposits averages 45°.

Two north-south zones of faulting are distinguished. The most important is the Nuektaminsky shear zone which limits the expansion of mineralisation to the east.

The movement along the Nuektaminsky fault is left-lateral. The next is the Granichny shear zone with right-lateral movement. The Granichny fault is a splay off the Nuektaminsky fault and together they form a V-shape, which represents a zone of tension. The Granichny shear zone hosts two vertical deposits (Semenovsky and Granichny) that cross-cut the stratigraphy.

The silver mineralisation is epigenetic. This is particularly clear at the Nizhny Endybal deposit, where the mineralised strata-bound zones exhibit structural deformation. The strata-bound veins and cross-cutting fracture systems in the region are associated with shearing. This is reflected in the common occurrence of parallel layers of slip planes along the boundaries of the sandstone beds and selvages of strata-bound veins, such as Mikhailovsky, Olgina, Vasilievsky and Anglesite-Cerussite. The structural analysis of joints in the mineralised rocks shows the ubiquitous existence of overthrusting dislocations (Kostin et al. 1997).

The Endybal diatreme and quartz porphyry dykes postdate the overthrust event. The geological studies by JSC Yangeologia (2000) and by Kostin et al. (1997) have led to the following conclusions regarding the sequence of events:

1. mineralised layers of sandstone containing sulphide mineralisation
2. structural deformation
3. Endybal diatreme.

## 7.3 MINERALISATION

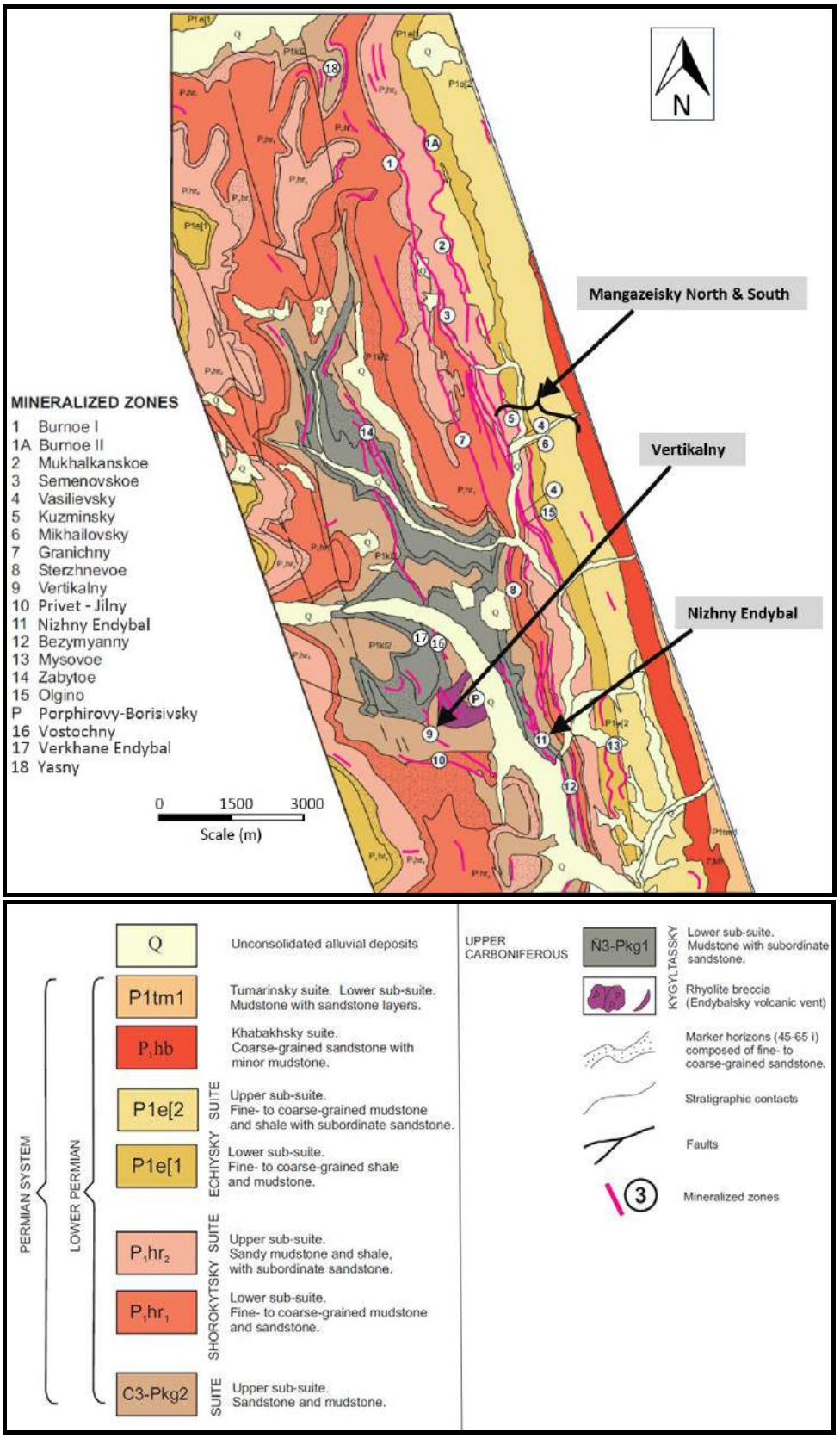
This region of Yakutia is known to contain many silver deposits; Figure 7.2 illustrates the position of the Property in relation to a number of the known silver projects in the region.

**Figure 7.2 Silver Projects within the Sakha Republic of Yakutia**

Source: Silver Bear

The Property contains several explored areas that host more than 100 occurrences of mineralisation. The mineral occurrences are concentrated within a 35-km long corridor. These main mineralised areas include: Yasny, Burny, Mukhalkansky, Zabyty, Zabyty-2, Mangazeisky, Strezhevoy, Vertikalny, Porfirovy-Borisovsky, Vostochny, Nizhny Endybal (NizhneEndybal), VerkhneEndybal, Jilny, Bezymyanny, Orogondia and Kis-Kuel, as illustrated in Figure 7.3.

**Figure 7.3 Exploration Targets and Property Geology**




Source: Tetra Tech
Notes: Orogondia and Kis-Kuel located further south than then southern extent of Figure 7.3.

The Property hosts at least four different types of mineralisation:

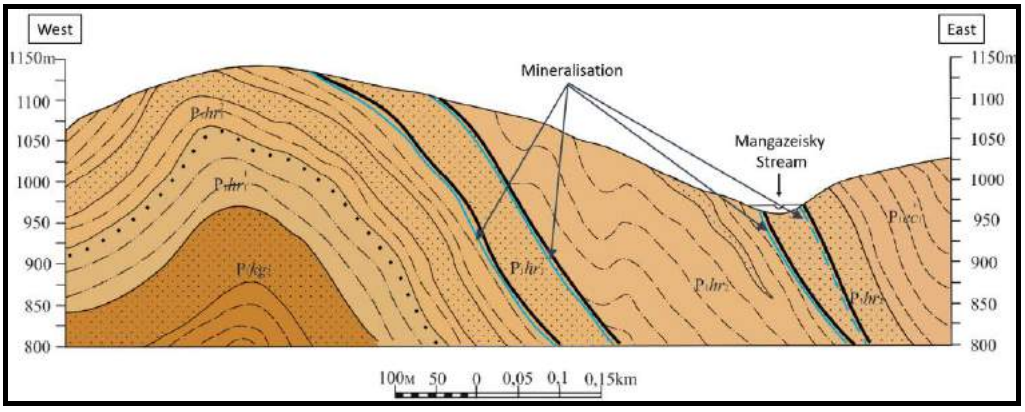
- Strata-bound silver-bearing, quartz-carbonate-sulphide structures with average grades greater than 900 g/t silver, with lead and zinc by-products. These silver bearing structures were mapped and sampled over an area of 65 km$^2$. Examples of this are the Vasilievsky–Anglesite-Cerussite and Olgina–Mikhailovsky veins within the Mangazeisky zone.
- Thicker linear-type stockwork areas with carbonate-silver sulphosalt mineralisation. Examples of this occur in the Strezhevoy and Nizhny Endybal Zones.
- Narrow, steep dipping veins such as Vertikalny that cross-cut stratigraphy and feature grades in excess of 1,000 g/t silver over widths ranging from several centimetres to several metres. Vertikalny and possibly Zabyty and Kis-Kuel are examples of this style of mineralisation.
- A porphyry area associated with quartz, quartz-carbonate and quartz-sulphide veins and veinlets, hosted by extrusive rhyolite porphyry. Porfirovy is an example of this.

Each mineralised area is described in the following sections.

### 7.3.1 MANGAZEISKY

The area is dominated by a north-north west/ south-south east striking anticlinal fold, Figure 7.4. Bedding planes and mineralisation dips at between 20 and 40° towards the east.

**Figure 7.4 West to East Cross Section through Mangazeisky North**




Source: Silver Bear

The mineralization of Mangazeisky North is mainly associated with banded brecciated textures. The following minerals are present: Native silver, acanthite, stephanite, polybasite, canfieldite, pyrargyrite, miargyrite, diaphorite, tetrahedrite, owyheeite, freieslebenite, boulangerite, arsenopyrite, sphalerite, pyrite, galena and chalcopyrite.

The veins are strata-bound, occurring on contacts between strata, particularly around sandstone units, and tend to be dilated towards the hinge of the local fold structure. It is noted that the strongest silver mineralisation occurs within the central core of the veins, this also correlates with the zones of strongest oxidation.

Brecciated sandstones have a thickness up to 0.5 m with the contacts of the brecciated zones being sharp and defined by early shearing. The shear commonly exhibits slickensides with horizontal striations. Brecciation was also accompanied by silicification of the finely laminated fine-grained sandstones. The cement is represented by medium grained quartz and fine-grained light grey siderite. The interpretation of tectonic stress fields for the southern flank of the Vasilievsky Zone (Kostin et al. 1997) indicates that mineralised shoots formed in areas where both vertical and horizontal displacement occurred.

### 7.3.2 VERTIKALNY

The Vertikalny vein has been traced on surface for 5.1 km. The under-explored southeast portion, identified in 1990 by Yangeologia, possibly extends to the Endybal River valley. To the northeast, along the areas where oxide material is identified, the vein swells from 3 to 15 m. Further northeast, the zone splits into two. The eastern branch, which is obscured by a siltstone bed, was traced by individual grab samples in erosional windows.

The mineralisation occurs as sandstone breccias with quartz or siderite cement, abundant hydrous ferric oxides that results from the oxidation of sphalerite and galena. In the Northwest Zone, potential mineralisation was traced in float and frost heaves up to the head of Krainy Creek. Further along, the mineral zone enters the right side of the Sirelendge River, where it is tested by trenches and found to contain galena-siderite mineralisation. Along the entire length, mineralisation is expressed as breccias with siderite-sphalerite-galena and various quantities of silver sulphosalts. Mineralisation is usually associated with the presence of dykes of intermediate to basic composition.

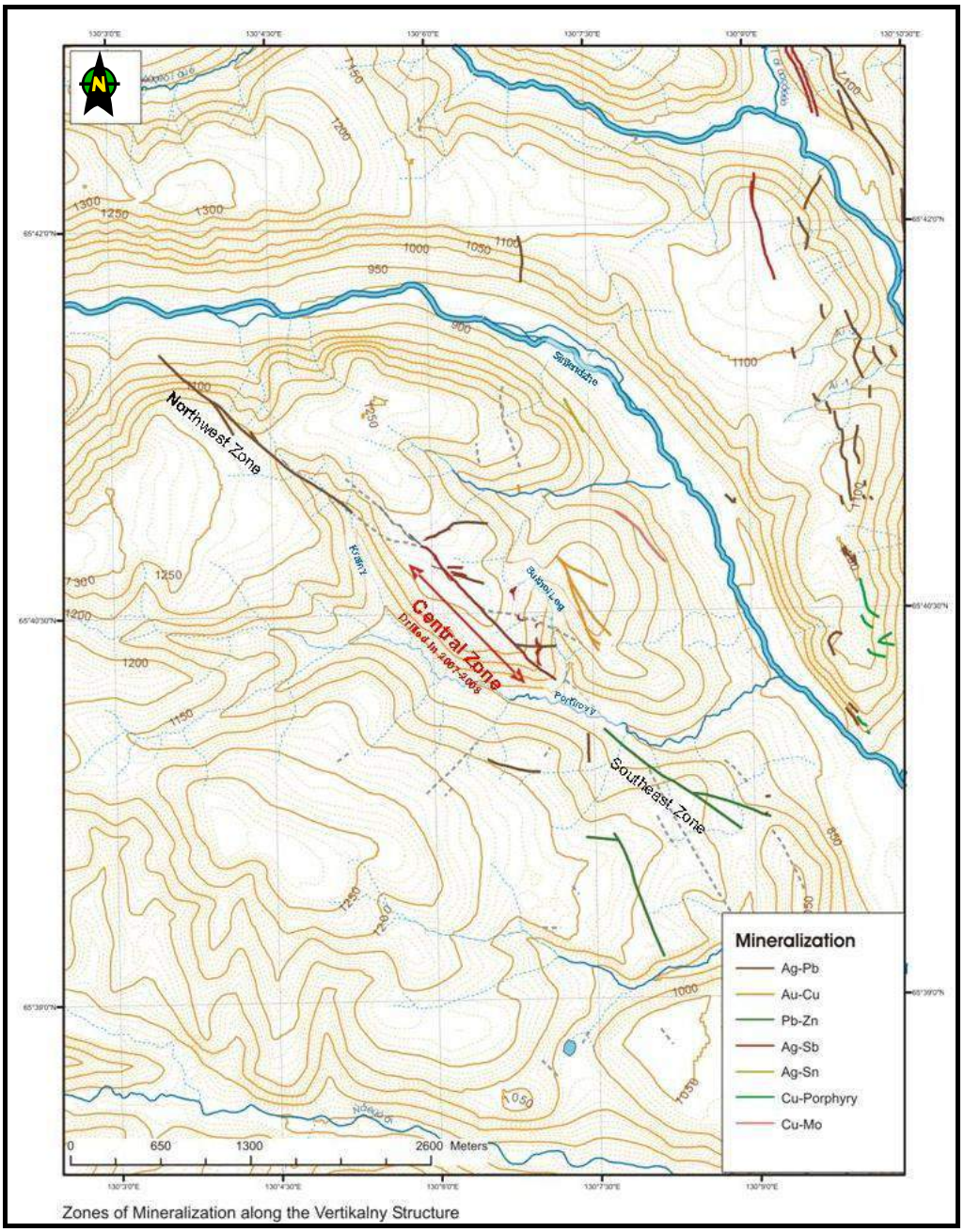
The Vertikalny Zone is not a single linear feature, but rather a combination of conjugated faults and breccias with various mineral compositions and quality. Structurally, the Vertikalny Zone is associated with the right-lateral strike-slip fault zone, which can be readily identified on IKONOS satellite images. Exploration of the structure has revealed sub-parallel branches with potentially prospective mineralisation similar to that found in the Central Zone. The intersections of the main structure and vein splays can result in the development of thicker intersections of mineralisation.

The mineral composition along the length of the Vertikalny structure is represented by galena and sphalerite, with subordinate values of other sulphides. However, early geochemical association analysis has shown three mineralisation types, which characterise the zones: The Northwest Zone (silver-lead-zinc), the Central Zone (silver-lead-zinc-tin) and the Southeast Zone (lead-zinc).

The three zones of the Vertikalny structure are presented in Figure 7.5.

The total drilled strike length of the Vertikalny structure is some 2,400 m. Drilling has tested portions of the structure to a maximum depth of 500 m from surface. Figure 7.6 shows a cored mineralised intersection from drillhole V13-020.

**Figure 7.5 Mineral Zonation of the Vertikalny Structure**




Source: Silver Bear

**Figure 7.6 Beginning of the Mineralised Intersection from Drillhole V13-020**

Source: Silver Bear

### 7.3.3 ZABYTY AND ZABYTY-2

The Zabyty occurrence was discovered in 1934 and further explored in 1992 to 1994. Mineral occurrences are concentrated on the walls and in the watershed of the Fedor-Yuryage River.

This area is referred to as the 'up-structure' of the Endybal anticline and is composed of nearly horizontal beds of sandstones and siltstones (Kygyltassky Suite). The stratigraphy is cut by sub-parallel; sub-vertical felsic dykes and later intermediate to basic dykes, of up to 5 m thick, which occur along a strike length of 2.5 km. The host rocks are sheared and broken by a number of fractures, often gouge-bearing, which control the branching, sub-parallel and steep-dipping zones of mineralisation. The structural disturbance is related to the Granichny fault system.

Mineralisation occurs as a structurally disturbed zone that intersects stratigraphy under a gravelite layer in the same stratigraphic level as the Strezhevoy mineralised body. The total width of the steeply dipping zone is 50 to 60 m (up to 2 km), striking at 315 to 340°. A single trench, developed by JSC Yangeologia in 1991, returned 1,906.5 g/t silver, 59.3% lead and 1.85% zinc from sandstone breccia cemented with sulphides.

The following minerals are present in the Zabyty occurrence: galena, sphalerite, tetrahedrite, chalcopyrite, pyrite, boulangerite and arsenopyrite. The association is silver-galena-sphalerite-siderite. Mineralisation occurs with galena, sphalerite and siderite-silver sulphosalt aggregates.

There are two parallel zones of mineralisation located within 200 to 300 m from each other – the Western and Eastern (Nekrasov et al. 2004).

The mineralisation potential is promising, given its structural and mineralogical similarity with Vertikalny. It is evident from the IKONOS satellite image that the potentially mineralised areas of Zabyty can be traced south toward the Porfirovy site.

### 7.3.4 KIS-KUEL

The Kis-Kuel site is located approximate 20 km southeast of Vertikalny, in the western limb of the Endybal anticline.

The geology at Kis-Kuel consists of granitoid intrusive bodies beneath sedimentary units. The sediments above the stocks contain veinlets of sphalerite. The stock itself hosts quartz-galena-chalcopyrite veinlets, brecciated intermediate dykes, brecciated sandstone with argentiferous healed with galena-quartz cements, oxidised intrusive with disseminated sulphides. In most cases the stock is obscured by the overlying sediments.

The mineralisation is controlled by linear structures associated with the Nuektaminsky fault as well as structures formed during the crystallisation of the Kis-Kuel pluton.

This style of mineralisation has no similarities to others seen on the exploration licence and therefore, warrants further investigation. Lead and zinc mineralisation, previously only seen in the margins of intrusive bodies, occurs in the centre of the Kis-Kuel pluton, which might indicate the presence of an undiscovered copper–molybdenum or gold-copper porphyry. There are also several occurrences of arsenopyrite-quartz veining, which indicates the potential for gold mineralisation.

### 7.3.5 OROGONDIA

Based on data by V.V. Shoshin (Nekrasov. et al. 1997) mineralisation at Orogondia is connected with a near conformable mineralised zone of shearing with a strike of 325 to 345° that can be traced for up to 4 km. Most of the mineralisation reports on the surface of medium-grained sandstones as sulphide-quartz-siderite veinlets, of 0.5 to 2 m wide (average thickness is 0.8 m).

The reported length of the mineralised body is circa 1 km.

The grade varies from 138 to 886 g/t silver, 4.83 to 25.44% lead, and 2.12 to 7.78% zinc. The following minerals are present: galena, sphalerite, pyrite, tetrahedrite, arsenopyrite, chalcopyrite, stannite, owyheeite, diaphorite, boulangerite. Based on the data from Yangeologia, the Orogondia showing was evaluated from nine grab samples, selected from float and subcrop.

Mapping and prospecting in 2008 led to the discovery of a strata-bound zone of oxidised quartz-carbonate which measures 0.8 m wide, with a strike length of 200 to 1,200 m. This occurrence is described as potentially non-argentiferous as it contains only sparse quantities of disseminated sphalerite and galena.

The work in 2008 failed to locate the occurrences of the mineralisation as reported by JSC Yangeologia (2000) within 4 km of its proposed location. It is likely that there were several different occurrences, which combined and appeared to be a single feature.

### 7.3.6 STERZHNEVOY

This zone is a complex vein system of approximately 600 m in length with a thickness of up to 5 m, but averaging approximately 0.9 m. The thickness of the individual veins within the larger vein system varies from 10 to 20 cm. In addition, parallel mineral zones are associated with the main deposit. The average grade of silver of the zone is 2,652 g/t. The mineralised veins are situated within medium and coarse-grained sandstones and siltstones, overlying a lower conglomerate unit. A significant amount of a black organic substance (shungite) is present in the cement, binding the particles of the sedimentary units together. In the areas where there has been hydrothermal reworking of the sandstones, shungite forms lenses and flakes in association with coarse-crystalline drusy quartz. The underlying layers of sandstone contain disseminated silver mineralisation and are within the same stratigraphy as the Nizhny Endybal deposit.

The Sterzhnevoy Zone was formed as a result of remobilised mineralisation from underlying silver rich sulphide-bearing sandstones, into structures formed in a shear zone with numerous secondary downthrown blocks and overthrusts (Kostin et. al. 1997). There is a downthrown layer with a thick zone of boudinage and jointing situated parallel to the main zone. The Sterzhnevoy Zone can be traced from the Bezymyanny deposit to the Zabyty mineral occurrence and is characterised by barren hydrothermal activity, expressed in remobilisation of an organic substance (shungite) and the formation of quartz druses from sandstone.

Tracing the hydrothermal rock alterations through the boudinage zone along the strike of the siltstone layer to the north of the Sterzhnevoy Zone as indicated by the preservation of the vein and rock alterations (quartz crystals druses, lenses and shungite flakes) shows that silver mineralisation is absent. The assumption is that the mineral components for the Sterzhnevoy Zone were taken from stratigraphically underlying rocks of the Nizhny Endybal deposit and hydrothermal activity channelled their remobilisation into more favourable structures.

### 7.3.7 MUKHALKANSKY

The Mukhalkansky mineralisation is represented by two galena bearing veins. The first vein, which cross-cuts the stratigraphy has been traced for 800 m and has an average width of 0.2 m and contains an average silver content of 1,295.4 g/t. The vein is confined to a tectonic fault that was accompanied by brecciation of the enclosing rocks during its formation. The vein is orientated parallel to the Nuektaminsky fault and is believed to be its mineralisation supplying fragment. The second vein is a concordant vein in its mode of occurrence and is confined to a stratum of thin layer sandstones. The second vein branch can be traced for approximately 500 m and has a width of between 0.2 and 0.4 m. The average silver content of the second vein is 2,328.7 g/t.

### 7.3.8 BEZYMYANNY

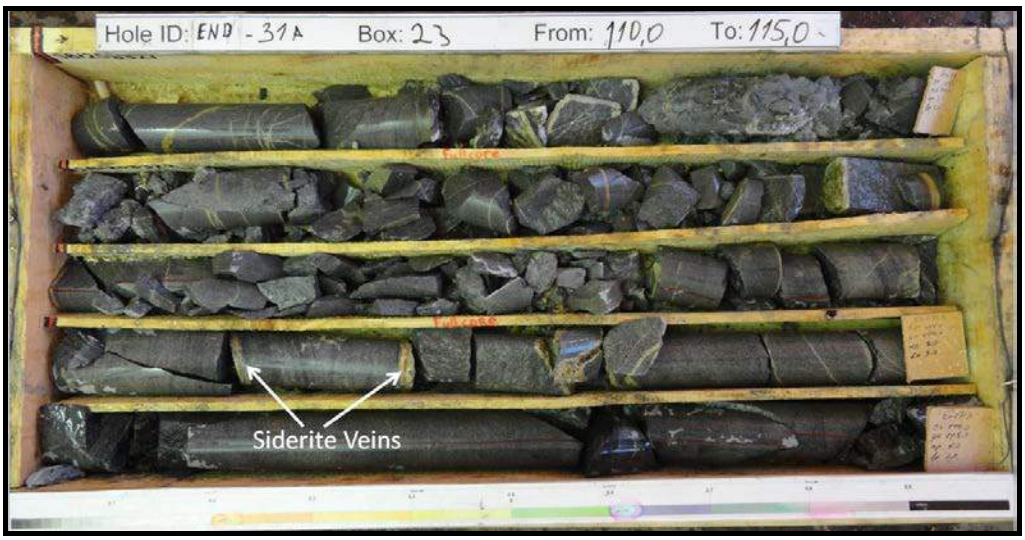
The Bezymyanny mineralisation is composed of several zones confined to inter-stratal ruptures. The mineral veins are located along the contacts of medium-grained and fine-grained sandstone strata. Veins are traced for 500 m with a thickness ranging

from between 2 to 5 cm and 34 to 40 cm. The mineralisation content varies from 756 to 24,433 g/t silver, 0.4 to 1.5 g/t gold, 0.1 to 7.81% lead and 0.1 to 0.8% zinc.

### 7.3.9 NIZHNY ENDYBAL

The Nizhny Endybal deposit has been known since 1774 under the name "Kokovin Silver Mine". The style of the mineralisation at Nizhny Endybal takes the form of a stockwork style network of thin veins, as illustrated in Figure 7.7. Concentrations of the stockwork are accumulated into lens shaped bodies as shown in Figure 7.8. The mineralisation is associated with siderite veins, which are principally parallel or sub-parallel to bedding. However, occasional sub-vertical veins are present, which cross-cut the bedding planes. The veins are predominantly 1 to 2 cm in thickness, but occasionally up to 10 to 15 cm. The thicker veins include veinlets of fahlore and vugs filled with fahlore crystals (refer to Figure 7.11 and Figure 7.12). Galena may also be present as separate veins, but the silver mineralisation does not appear to be directly related to the presence of galena.

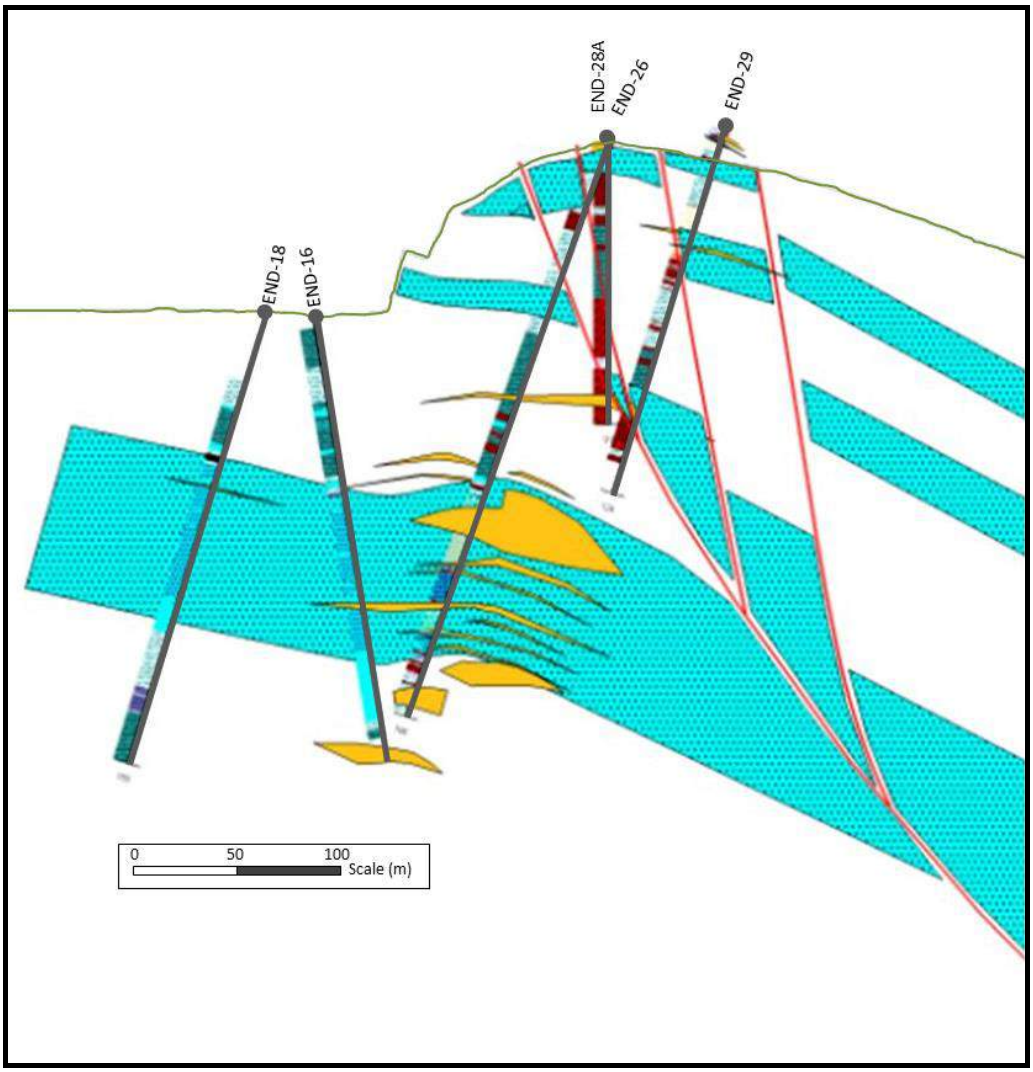
**Figure 7.7 Stratiform Siderite Veining in Drillhole END-31A**




Source: Silver Bear (2012)

The mineralisation is concentrated within the fold axis of the anticline and decreases with distance along the fold limbs from the axis. If a transect is taken approximately east-west, perpendicular to the fold axis, the thickness of the intersections and mean silver grades decrease to negligible at a distance of circa 40 to 50 m from the centre of the fold axis (illustrated in cross-section in Figure 7.8). In general, the width of the mineralised zones west to east (across strike) is approximately 80 to 100 m and has a continuous strike length of approximately 700 m. Discontinuous mineralisation has been traced in recent drilling to a distance of approximately 1,300 m along strike.

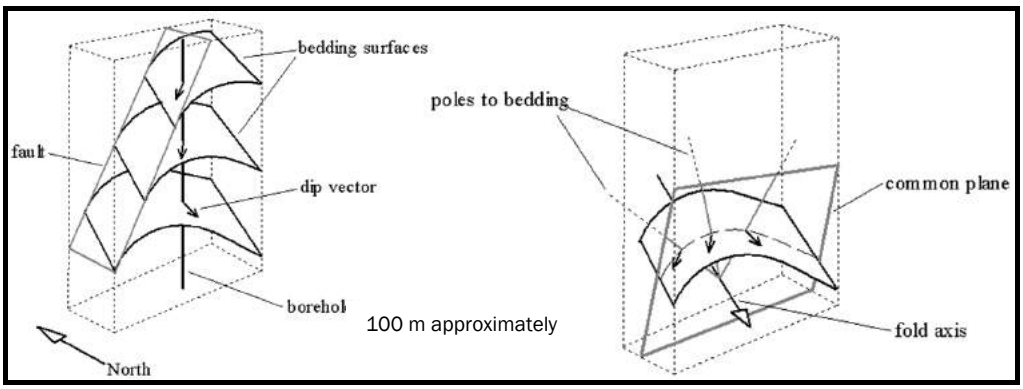
**Figure 7.8 Vertical Cross-Section through Drillholes END-16, END-18, END-26, END-28A and END-29 Looking North**




Source: Silver Bear (2012)
Note: Yellow = Lenses of mineralisation developed in antiform; Blue = sandstone units.

Structurally, the mineralisation at Nizhny Endybal is thought to relate to an antiformal thrust zone with associated anticline system. The structure is interpreted to include a series of listric faults and is illustrated in Figure 7.9.

**Figure 7.9 Representation of the Geometry of the Interpreted Structural Features**




Source: Silver Bear

The mineralisation at Nizhny Endybal is contained within a series of interbedded sandstone and silty-sandstone units. It is thought that the silty-sandstone units have a lower permeability than the adjacent sandstone units and have, therefore, inhibited the flow of fluids. The sandstones are anticipated to have higher permeability and are more readily fractured and, as such, have provided preferential pathways for fluid flow and associated mineralisation.

Three major sandstone units have been highlighted within the interbedded sequence at Nizhny Endybal. The average thicknesses of the units are 17 m, 22 m and 60 m. The upper and middle units are 17 m and 22 m in thickness and comprise fine and medium-grained sandstones. The lower unit is 60 m in thickness and comprises coarse-grained sandstones. The significant mineralised intersections are associated with layers of medium-grained sandstones.

Figure 7.10 shows a general view of the prospect area, with the deposit prominent in the cliff face.

**Figure 7.10 General View of Nizhny Endybal**

Source: Tetra Tech

**Figure 7.11 Siderite Vein with Vugs filled with Fahlore Crystals, Galena, Ankerite and Quartz**

Source: Silver Bear

**Figure 7.12 Siderite Vein with Tetrahedrite Crystal**

Source: Silver Bear

### 7.3.10 VERKHNE ENDYBAL

The watershed of the Sirelendge-Fedor and Yuryage rivers is prospective for silver mineralisation. Several grab samples selected from among frost heave, characterise disseminated and vein-like mineralisation in altered sandstones.

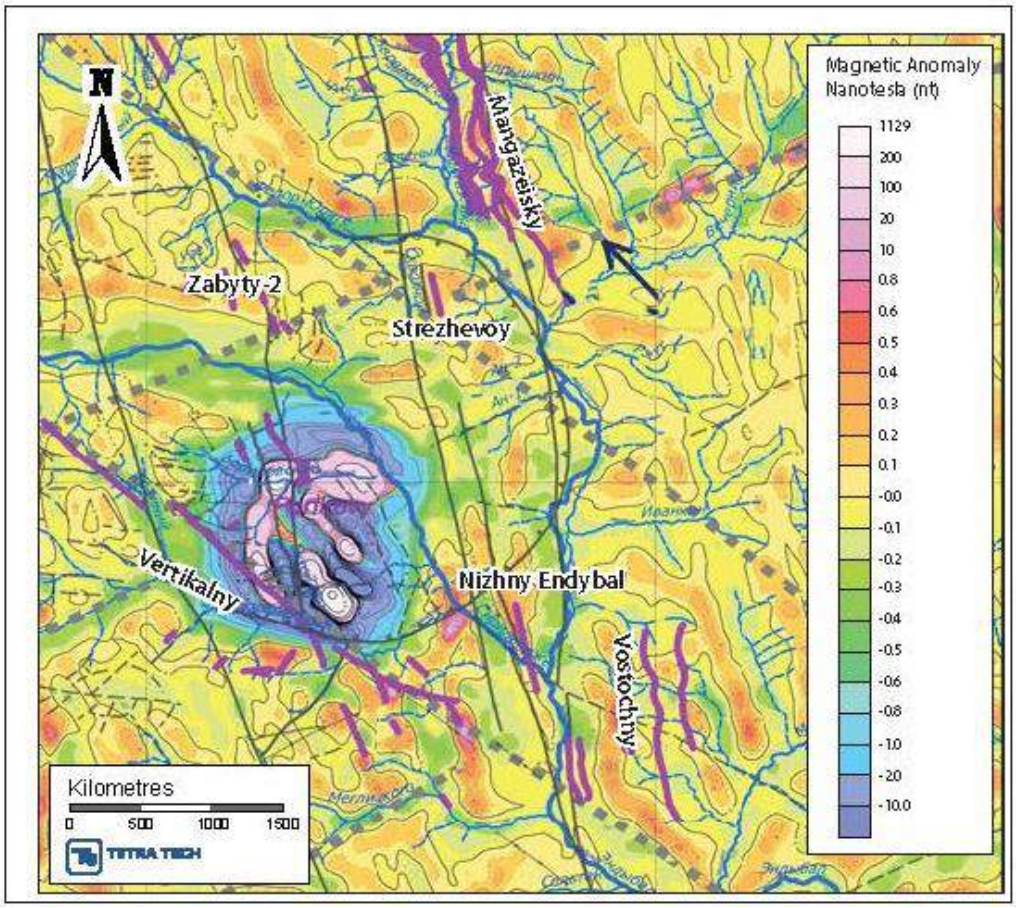
### 7.3.11 PORFIROVY

Mineralisation in the Porfirovy area is associated with quartz, quartz-carbonate and quartz-sulphide veins and veinlets hosted by rhyolite and dacite porphyry.

The copper and gold potential of the area has only recently been recognised and the copper-silver soil geochemical results indicate an anomalous area that corresponds with the intrusive complex. Locally the rhyolite has been silicified and the feldspars exhibit argillic alteration.

The porphyry is well defined by the magnetic anomaly survey (Figure 7.13).

**Figure 7.13 Magnetic Anomaly Map**




Source: Silver Bear

## 7.3.12 BORISOVSKY

Borisovsky occurs on the terrace along the northeast wall of the Sirelendge River in the mouth of the Borisovsky Creek to the northwest. Outcrop with fragments of quartz-carbonate breccias with dispersed sulphides (mostly pyrite) as pockets and veinlets were found within the zone. According to the IKONOS satellite image the outcrops are correlated with two disturbed lines of north-western trend (330°), named Zapadny and Vostochny.

At Zapadny, 1.5 mm quartz-filled fractures, quartz-carbonate breccias and quartz-siderite formations with dispersed pyrite veinlets are hosted within fine and medium-grained sandstones. The structures general trend is 075°.

The Vostochny fault zone was traced for 400 m to the northwest along the wall of the northeastern terrace of the Sirelendge River by sporadic fragments of yellow-white quartz and quartz-siderite with sulphide (pyrite, rare galena) mineralisation. In the northwestern part of this zone, grab samples are of pyrite and galena that occur as disseminated inclusions in yellow-white quartz with pockets of siderite.

# 8.0 DEPOSIT TYPES

The Property contains two main deposit types: epigenetic polymetallic silver-lead-zinc veins (metasediment hosted), and porphyry (copper, gold, silver). The majority of the exploration, and the existing resources, are focused upon the polymetallic silver-lead-zinc veins. The veins are sulphide-rich, containing sphalerite, galena, silver, and sulphosalt minerals in a carbonate and quartz gangue.

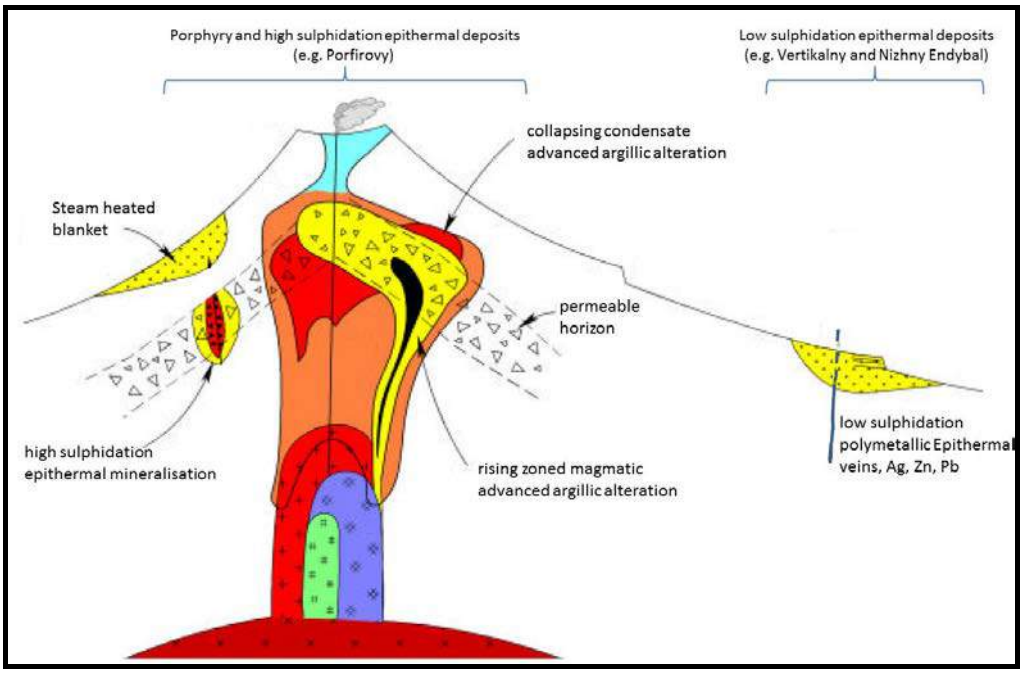
At Vertikalny the veins are emplaced in and along fractures and faults in a sedimentary basin dominated by clastic rocks that have been deformed, metamorphosed, and intruded by igneous rocks. The veins are steeply dipping and narrow.

At Nizhny Endybal a stockwork of cross-cutting polymetallic veins are concentrated within strataform lenses of sandstone and siltstone. The mineralisation is concentrated to the centre of the Endybal anticline fold axis.

In many cases, the geology and morphology of the veins appear to be similar to the Prognoz property, which Nordgold NV is developing some 160 km to the east of the Property. The Porfirovy area of the Property represents a potential copper-gold-silver porphyry deposit, related to a sub-volcanic intrusive body.

Figure 8.1 presents a section through a conceptual porphyry and epithermal deposit model that could be applied to parts of the Mangazeisky licence.

**Figure 8.1 Idealised Section through a Porphyry and Epithermal Deposit Model**




Source: Corbett (2009)

## 8.1 GEOLOGICAL CONCEPTS BEHIND EXPLORATION PROGRAMME

At Vertikalny and Nizhny Endybal, structural geology influences the extent and distribution of the mineralisation. Surface trenching and diamond drilling campaigns have been targeted to systematically explore profiles along the strike length of the interpreted structural features (i.e. along the fractures and faults at Vertikalny, and along the fold axis of the Endybal anticline).

Geological mapping, historical geophysical surveys, and soil sampling campaigns guided the initial drilling and trenching programmes.

# 9.0 EXPLORATION

## 9.1 2004 TO 2010 EXPLORATION PROGRAMME SUMMARY

The exploration campaigns completed prior to 2010 have been disclosed in Wardrop (2011) completed by Tetra Tech (formerly Wardrop Engineering Inc). Table 9.1 provides a summary of the exploration completed prior to 2015.

Early exploration by Prognoz, Silver Bear's subsidiary, was focused upon the narrow, strata-bound silver mineralisation of the Vasilievsky and Mikhailovsky veins at Mangazeisky North. From 2007, the focus shifted to the development of the Vertikalny deposit and included the exploration activities on the thicker, linear, stockworks at Nizhny Endybal.

**Table 9.1 Historic Exploration Activities at the Property**

| Year | Exploration Activities | Targets Explored |
|---|---|---|
| 2004 | No trench exploration was undertaken during 2004. | - |
| 2005 | 9,641 $m^3$ of trenching. | Vasilievsky, Mikhailovsky, Sterzhnevoy, Nizhny Endybal |
| 2006 | 4,843 $m^3$ of trenching and mapping. | Nizhny Endybal, Vostochny, Sterzhnevoy, Vertikalny |
| 2007 | 8,000 $m^3$ of trenching. | Vertikalny |
| 2008 | 22,633 $m^3$ of trenching.<br>Mapping, lithochemical sampling, direct current induced polarisation/magnetotellurics and magnetic anomaly geophysical surveys. | Vertikalny, Zabyty, Zabyty-2, Kis-Kuel, Orogondia |
| 2009 | 15,067 $m^3$ of trenching.<br>Lithochemical sampling, magnetic anomaly mapping. | Nizhny Endybal, Vertikalny, Kis-Kuel, Mukhalkan-Burny |
| 2010 | No exploration was undertaken during 2010. | - |
| 2011-2012 | 1,600 $m^3$ of trenching. | Nizhny Endybal |
| 2013 | 52 trenches at regular intervals with 474 m of sampling. | Mangazeisky North and South |
| 2014 | 19 trenches across multiple exploration targets. | Vertikalny, Mangazeisky South, Porfirovy and Sterzhnevoy |
| 2015 | 8 trenches for a total length of 598 m. | Porfirovy and Sterzhnevoy |

## 9.2 2011 AND 2012 EXPLORATION PROGRAMME

Silver Bear re-commenced exploration work during the 2011 and 2012 field seasons, which included a trenching programme. A further six trenches were excavated within the central part of the Nizhny Endybal deposit, totalling 1,600 $m^3$.

Table 9.2 presents a summary of the significant mineralised intersections from the trenches excavated at Nizhny Endybal during in 2011 and 2012.

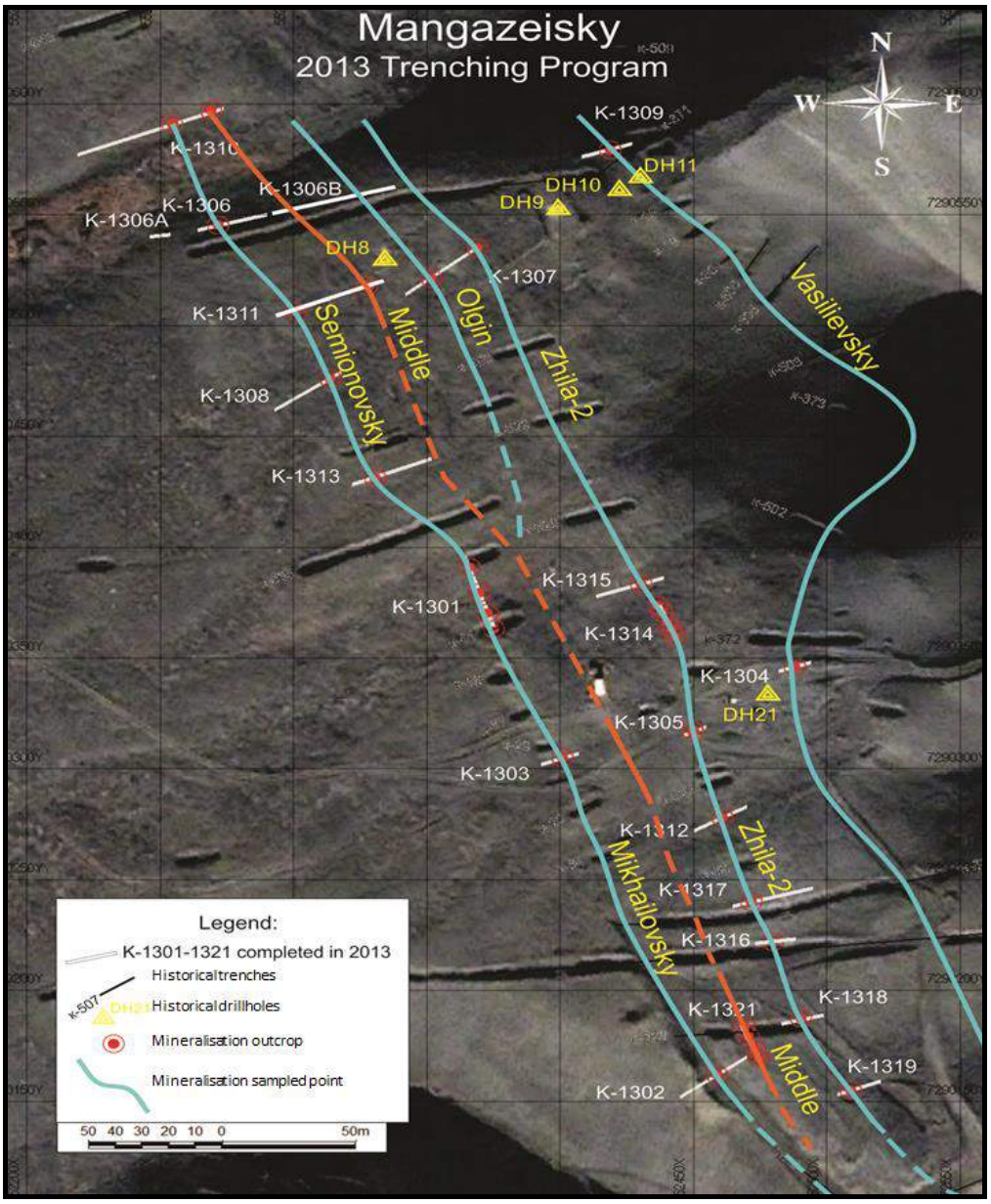
**Table 9.2 Summary of Intersections from 2011 to 2012 Trenches at Nizhny Endybal with a Silver Grade of >75 g/t**

| Trenches | From (m) | To (m) | Intersection Length (m) | Ag (g/t) |
|---|---|---|---|---|
| K-6049 | 19.0 | 43.0 | 24.0 | 162.0 |
| *including* | 19.0 | 20.0 | 1.0 | 807.0 |
| *including* | 32.0 | 33.0 | 1.0 | 1,420.0 |
| K-6051 | 47.5 | 51.8 | 4.1 | 82.3 |
| *including* | 51.6 | 51.8 | 0.2 | 175.0 |
| K-6053 | 16.0 | 18.0 | 2.0 | 486.0 |
| *including* | 16.1 | 17.1 | 1.0 | 683.0 |
| K-6053 | 37.0 | 41.0 | 4.0 | 136.0 |
| *including* | 37.0 | 38.0 | 1.0 | 225.0 |

## 9.3 2013 EXPLORATION PROGRAMME

During the summer of 2013, exploration shifted focused on Mangazeisky North and South, where 52 trenches were excavated at regular intervals normal to the mineralised structure. A total of 474 m of sampled material was collected. Figure 9.1 illustrates the location of the 2013 trenches in relation to the mineralised veins at Mangazeisky North.

**Figure 9.1 Plan Illustrating 2013 Trench Locations on Mangazeisky North Zone**




Source: Silver Bear, Tetra Tech

Table 9.3 presents a summary of significant trench intersections on the Mangazeisky North deposit.

**Table 9.3 Summary of Intersections from 2013 Trenches on Mangazeisky North; with a Silver Grade of >75 g/t Ag**

| Trench ID | Sample Profile No. | Sample Length Across Strike (m) | Ag Grade (g/t) | Mangazeisky North Target Vein |
|---|---|---|---|---|
| k13-01 | P1 | 1.9 | 1,705.0 | Mikhailovsky |
| k13-01 | P2 | 2.1 | 1,590.0 | Mikhailovsky |
| k13-01 | P3 | 2.0 | 1,700.0 | Mikhailovsky |
| k13-01 | P4 | 1.6 | 1,780.0 | Mikhailovsky |
| k13-01 | P5 | 2.0 | 2,032.0 | Mikhailovsky |
| k13-01 | P6 | 0.5 | 2,123.0 | Mikhailovsky |
| k13-03 | p1 | 1.0 | 129.0 | Mikhailovsky |
| k13-03 | p10 | 1.0 | 264.0 | Mikhailovsky |
| k13-03 | p7 | 1.0 | 302.0 | Mikhailovsky |
| k13-03 | p8 | 1.0 | 102.0 | Mikhailovsky |
| k13-11 | P1 | 1.0 | 267.0 | Mikhailovsky |
| k13-11 | P2 | 1.0 | 343.0 | Mikhailovsky |
| k13-11 | P3 | 1.0 | 99.6 | Mikhailovsky |
| k13-13 | P1 | 0.4 | 506.0 | Mikhailovsky |
| k13-13 | P2 | 0.8 | 157.0 | Mikhailovsky |
| k13-22 | P1 | 1.7 | 2,280.0 | Mikhailovsky |
| k13-22 | P2 | 1.6 | 2,575.0 | Mikhailovsky |
| k13-22 | P3 | 1.6 | 2,017.0 | Mikhailovsky |
| k13-22 | P4 | 1.2 | 2,090.0 | Mikhailovsky |
| k13-22 | P5 | 1.0 | 874.0 | Mikhailovsky |
| k13-22 | P6 | 1.2 | 1,262.0 | Mikhailovsky |
| k13-22 | P7 | 1.1 | 932.0 | Mikhailovsky |
| k13-23 | P3 | 1.0 | 90.5 | Mikhailovsky |
| k13-24 | P1 | 0.7 | 2,774.0 | Mikhailovsky |
| k13-24 | P2 | 0.8 | 191.0 | Mikhailovsky |
| k13-04 | P1 | 1.0 | 221.0 | Vasilievsky |
| k13-04 | P2 | 1.0 | 79.6 | Vasilievsky |
| k13-04 | P3 | 1.0 | 334.0 | Vasilievsky |
| k13-04 | P4 | 1.0 | 308.0 | Vasilievsky |
| k13-05 | P1 | 1.0 | 484.0 | Zhila-2 |
| k13-05 | P2 | 1.0 | 186.0 | Zhila-2 |
| k13-05 | P3 | 1.0 | 1,224.0 | Zhila-2 |
| k13-05 | P4 | 1.0 | 1,232.0 | Zhila-2 |
| k13-05 | P5 | 1.0 | 370.0 | Zhila-2 |
| k13-12 | P1 | 0.6 | 90.0 | Zhila-2 |
| k13-12 | P2 | 0.4 | 1,364.0 | Zhila-2 |
| k13-14 | P1 | 1.5 | 1,504.0 | Zhila-2 |
| k13-14 | P2 | 0.3 | 2,543.0 | Zhila-2 |
| k13-14 | P3 | 0.9 | 1,730.0 | Zhila-2 |
| k13-14 | P4 | 1.4 | 1,026.0 | Zhila-2 |
| k13-14 | P5 | 2.2 | 768.0 | Zhila-2 |
| k13-15 | P1 | 0.5 | 2,166.0 | Zhila-2 |

*table continues...*

| Trench ID | Sample Profile No. | Sample Length Across Strike (m) | Ag Grade (g/t) | Mangazeisky North Target Vein |
|---|---|---|---|---|
| k13-16 | P1 | 0.25 | 218.0 | Zhila-2 |
| k13-16 | P2 | 1.2 | 2,665.0 | Zhila-2 |
| k13-16 | P3 | 0.25 | 80.6 | Zhila-2 |
| k13-17 | P1 | 1.0 | 375.0 | Zhila-2 |
| k13-17 | P2 | 0.5 | 2,144.0 | Zhila-2 |
| k13-18 | P1 | 0.3 | 1,964.0 | Zhila-2 |
| k13-18 | P2 | 0.8 | 105.0 | Zhila-2 |
| k13-18 | P3 | 0.3 | 1804.0 | Zhila-2 |

## 9.4 2014 EXPLORATION PROGRAMME

In 2014, a trenching programme was carried out on the Vertikalny, Mangazeisky South, Porfirovy and Sterzhnevoy exploration targets (Table 9.4).

**Table 9.4 Summary of Significant Intersections from 2014 Trenching Campaigns; Silver Grade of >100 g/t or Gold Grade >0.5 g/t**

| Trenches | From (m) | To (m) | Intersection Length (m) | Ag (g/t) | Au (g/t) | Deposit |
|---|---|---|---|---|---|---|
| MNS14-02 | 0.9 | 0.98 | 0.08 | 3,150 | - | Mangazeisky North |
| MNS14-03 | 0.9 | 0.98 | 0.08 | 3,066 | - | Mangazeisky North |
| KV14-03/1 | 8.7 | 11.1 | 2.4 | 912 | - | Vertikalny |
| including | 10.1 | 11.1 | 1 | 912 | - | Vertikalny |
| KV14-05 | 10.1 | 11.1 | 1 | 853 | - | Vertikalny |
| KS14-01 | 68.2 | 75 | 6.8 | 1,589 | - | Sterzhnevoy |
| including | 68.2 | 68.5 | 0.3 | 4,916 | - | Sterzhnevoy |
| KS14-02 | 78.1 | 101.2 | 23.1 | 3,234 | - | Sterzhnevoy |
| including | 78.1 | 78.6 | 0.5 | 7,019 | - | Sterzhnevoy |
| and | 99.9 | 100.2 | 0.3 | 13,938 | - | Sterzhnevoy |
| KS14-02 | 83.2 | 86.7 | 3.5 | 3,273 | - | Sterzhnevoy |
| including | 83.2 | 84 | 0.8 | 9,688 | - | Sterzhnevoy |
| KS14-02 | 93.7 | 94.3 | 0.6 | 1,005 | - | Sterzhnevoy |
| KS14-03 | 49.5 | 51.5 | 2 | 850 | - | Sterzhnevoy |
| including | 49.5 | 50.5 | 1 | 1,439 | - | Sterzhnevoy |
| KS14-03 | 56.1 | 58.1 | 2 | 2,373 | - | Sterzhnevoy |
| including | 56.1 | 57.1 | 1 | 4,507 | - | Sterzhnevoy |
| KS14-04 | 49.5 | 61.9 | 12.4 | 4,584 | - | Sterzhnevoy |
| including | 49.5 | 51.7 | 2.2 | 9,196 | - | Sterzhnevoy |
| and | 61.7 | 61.9 | 0.2 | 4,129 | - | Sterzhnevoy |
| TV14-04 ПР II | 2.2 | 4.9 | 2.7 | 602 | - | Vertikalny |
| including | 4.0 | 4.9 | 0.9 | 1,132 | - | Vertikalny |
| TV14-04 ПР IV | 2.5 | 3.2 | 0.7 | 269 | - | Vertikalny |
| TV14-04 ПР VI | 1.9 | 2.7 | 0.8 | 1,020 | - | Vertikalny |
| TV14-06 ПР VII | 4.1 | 4.4 | 0.3 | 1,203 | - | Vertikalny |

*table continues...*

| Trenches | From (m) | To (m) | Intersection Length (m) | Ag (g/t) | Au (g/t) | Deposit |
|---|---|---|---|---|---|---|
| TV14-04 пр 2 | 4.0 | 4.9 | 0.9 | 1,141 | - | Vertikalny |
| KP14-08 | 0.0 | 6 | 6 | - | 0.71 | Porphyry |
| including | 0.0 | 1 | 1 | - | 2.44 | Porphyry |
| KP14-08 | 17.0 | 19 | 2 | - | 0.52 | Porphyry |
| including | 17.0 | 18 | 1 | - | 0.86 | Porphyry |
| KP14-08 | 34.0 | 35 | 1 | - | 0.79 | Porphyry |

## 9.5 2015 EXPLORATION PROGRAMME

The 2015 exploration campaigns focused on trenching at Sterzhnevoy and Porphirivoy. In total, six trenches were excavated at Sterzhnevoy, with a total length of 395 m. At Porphirivoy, three trenches were excavated, with a total length of 203 m.

One notable intercept was noted at Sterzhnevoy, with a grade of 283 g/t silver over a 1 m intercept in trench number SK15-03.

At Porphirivoy notable samples included 4.59 g/t gold over a 1 m intercept in trench number PR15-01 and 2.17 g/t gold over a 1 m intercept in trench number PR15-06.

## 9.6 TRENCH SAMPLING PROCEDURES

The current sampling methods and approaches are summarised as follows:

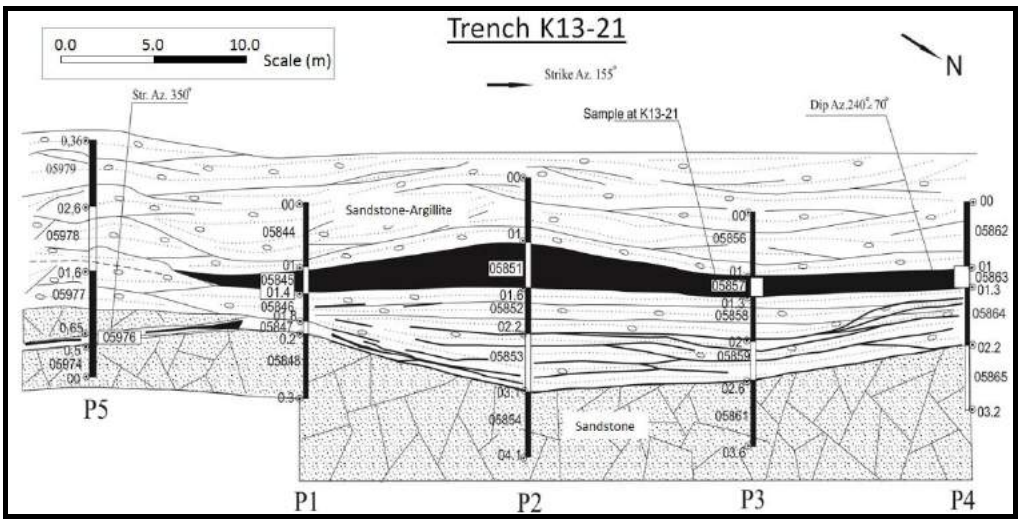
- A main trench was excavated over and along the strike of the mineralised zones to a depth of up to 4 m to expose the mineralised zones. The width of the trenches was 1 to 4 m depending on the thickness of the overburden.
- Where possible sampling and drilling is conducted on a grid of parallel lines (profiles) oriented perpendicular to the strike of the main mineralised zones. All trenches, road cuttings and other exposures were mapped in detail and sampled as required, Figure 9.2.
- Trench channel sampling was conducted perpendicular to the strike of the mineralised zones, the cross-section of which was 3 cm by 10 cm. The length of the samples varies from 0.1 to 6.0 m and averages 1 m. The entire trench exposure was sampled. Sample weights vary from 5 to 10 kg and average 7.5 kg.

All initial trench sampling was conducted on a grid of parallel profiles oriented perpendicular to the strike of the main mineralised zones. The sampled profiles were initially established at widely spaced intervals, which have been in-filled as exploration continues.

The initial trenches were dug along the strike of the mineralised zones to a depth of up to 4 m to expose the mineralised zones. The width of the trenches was generally

between 4 m and 5 m to allow full intersections to be taken as profiles orientated perpendicular to the strike of the mineralisation (Figure 9.2 and Figure 9.3).

**Figure 9.2 Example of Trench Mapping and Sample Profiling from K13-21**




Source: Silver Bear
Note: Az – azimuth

Samples were bagged, tagged and given a unique reference number, before being returned to camp on a daily basis, where the material is dried, crushed, split and assayed using the methods outlined in Section 11.0. As with the drill core samples, standard and blank samples are submitted every 20 samples, however, no field duplicates are collected.

**Figure 9.3 Sampling Profiles within Trench K13-21**

Source: Silver Bear

## 9.1 TETRA TECH OPINION

Tetra Tech is of the opinion that the exploration has generally been conducted using methods and procedures that are consistent with recognised industry best practices. However, the trench sampling has not been included in the grade interpolation due to statistically significant bias that is noted when comparing the trenches with nearby drillholes.

The bias may be due to natural mechanical enrichment at surface, or may have been introduced as a result of the manual channelling methods used to sample the trenches. The trenching also lacked QA/QC samples, which prevented full data verification to be undertaken.

Tetra Tech recommends further work to resample the trenches using a rock saw to cut a sample, where appropriate and a full QA/QC programme.

# 10.0 DRILLING

Details about the drilling campaigns completed prior to 2010 have been disclosed fully in the Wardrop (2011). The 2011 to 2012 drilling campaigns have been disclosed fully in Tetra Tech (2013). The details of the drilling at Mangaziesky North completed during 2015 are disclosed in the 2016 Technical Report (Tetra Tech 2016). All of these reports are filed under Silver Bear's profile on the CSAs SEDAR. Table 10.1 provides a summary of the drilling completed between 2004 and 2015. The 2015 drilling campaign at Vertikalny Central is described fully in Section 10.0.

**Table 10.1 Summary of Drilling on the Property**

| Year | Metres Drilled | Targets Drilled |
|---|---|---|
| 2004 | 151 | Vertikalny |
| 2005 | 3,370 | Vasilievsky, Mikhailovsky, Nizhny Endybal, Strezhevoy |
| 2006 | 732 | Vertikalny |
| 2007 | 3,100 | Vertikalny |
| 2008 | 11,663 | Vertikalny, Semenovsky, Vasilievsky |
| 2009 | 12,373 | Vertikalny |
| 2010 | - | No drilling undertaken |
| 2011 to 2012 | 13,445 | Vertikalny, Nizhny Endybal |
| 2013 to 2014 | 9,153 | Mangazeisky, Vertikalny |
| 2015 | 4,427 | Vertikalny North West, Mangazeisky North, Porphivory, Strezhevoy |

The most recent drilling campaign at Vertikalny main deposit was completed in 2015 and is detailed below.

## 10.1 DRILLING PROGRAMME 2015

### 10.1.1 VERTIKALNY DEPOSITS

Silver Bear re-commenced drilling during the 2015 field season. During this period, diamond drilling added a further six intersections of the Vertikalny Central vein and a further eight intersections through the Vertikalny Northwest mineralised structures.

The 2015 in-fill drilling programme was designed with the intention of increasing knowledge of the short-range variability of the mineralisation and to build confidence in the grade continuity. The drilling was focused on mineralisation at depth, within the Vertikalny Central Zone and Northwest Zone.

The 2015 drilling is inclined at between 55 and 70°, Vertikalny Central drilling is orientated towards the southwest (generally with a strike of 210 to 230°). The Vertikalny Northwest drilling is orientated towards the northeast (with a strike of 40°)

As a consequence of the drilling angle and the steeply dipping mineralisation, the true thickness of the mineralisation is between 40 and 50% of the drilled intersection lengths (see Table 10.2).

In order to provide representative mineralised samples of sufficient quantity for metallurgical testing, drillholes V13-35MET to V13-45MET were drilled at 80°, approaching the dip of the mineralized zone, which resulted in a greater intersection of mineralization. For these drillholes, the true mineralisation thickness is approximately 17% of the reported intersection length in Table 10.2.

Table 10.2 provides summary information relating to the 2015 drilling campaign.

**Table 10.2 Summary of 2015 Drillholes**

| Drillhole ID | Length Drilled (m) | Easting | Northing | Elevation (m) | Azimuth (°) | Dip (°) | Mineralised Intercept Length (m) | True Mineralisation Thickness (m) |
|---|---|---|---|---|---|---|---|---|
| VNW15-01 | 110.00 | 549210.16 | 7285405.14 | 1,233 | 40 | -60.00 | 1.0; 1.0 | 0.5; 0.5 |
| VNW15-02 | 105.00 | 549143.24 | 7285448.08 | 1,232 | 40 | -60.00 | 1.25 | 0.625 |
| VNW15-03 | 185.00 | 549108.08 | 7285444.11 | 1,233 | 40 | -60.00 | - | - |
| VNW15-04 | 188.00 | 549049.75 | 7285454.75 | 1,237 | 40 | -60.00 | - | - |
| VNW15-05 | 184.00 | 549024.01 | 7285484.53 | 1,236 | 40 | -60.00 | - | - |
| VNW15-06 | 313.00 | 548903.45 | 7285539.02 | 1,235 | 40 | -60.00 | - | - |
| VNW15-07 | 80.00 | 549251.19 | 7285377.23 | 1,233 | 40 | -60.00 | 1.00 | 0.5 |
| VNW15-08 | 204.00 | 549214.04 | 7285321.11 | 1,240 | 40 | -60.00 | 1.40 | 0.7 |
| V15-01 | 218.00 | 551218.10 | 7283974.47 | 1,116 | 210 | -65.00 | 1.00 | 0.5 |
| V15-02 | 257.00 | 551217.45 | 7283973.85 | 1,116 | 215 | -70.00 | 1.3; 2.9 | 0.65; 1.45 |
| V15-03 | 278.00 | 551268.89 | 7283959.53 | 1,081 | 220 | -66.00 | 1.1; 1.0 | 0.55; 0.5 |
| V15-04 | 221.00 | 551280.88 | 7283898.45 | 1,059 | 206 | -70.00 | 1.1; 1.7 | 0.55; 0.85 |
| V15-05 | 311.00 | 551320.88 | 7283945.43 | 1,048 | 230 | -63.00 | - | - |
| V15-06 | 230.00 | 551356.66 | 7283892.29 | 1,016 | 224 | -55.00 | 1.80 | 0.9 |

Significant intersections are tabulated in Table 10.3. Intersections are considered significant where silver has a length weighted grade of more than 100 g/t over a length of more than 1.0 m.

**Table 10.3 2013/2014 Drill Programme Significant Intersections; >1 m at >100 g/t Silver**

| Drillhole ID | From (m) | To (m) | Thickness (m) | Ag (g/t) |
|---|---|---|---|---|
| VNW15-01 | 81.5 | 82.5 | 1.00 | 385 |
| VNW15-01 | 83.5 | 84.5 | 1.00 | 203 |
| VNW15-02 | 98.2 | 99.45 | 1.25 | 187 |
| VNW15-07 | 56.0 | 57.0 | 1.00 | 154 |
| VNW15-08 | 197.2 | 198.7 | 1.50 | 1,816 |
| V15-01 | 208.5 | 209.5 | 1.00 | 210 |
| V15-02 | 96.0 | 97.3 | 1.30 | 123 |
| V15-02 | 244.5 | 247.4 | 2.90 | 596 |
| V15-03 | 266.0 | 267.1 | 1.10 | 137 |
| V15-03 | 269.5 | 270.5 | 1.00 | 110 |
| V15-04 | 211.7 | 212.8 | 1.10 | 176 |
| V15-04 | 213.1 | 214.8 | 1.70 | 344 |
| V15-06 | 217.6 | 219.4 | 1.80 | 153 |

The average and range of true thickness of mineralisation are outlined in Table 10.4.

**Table 10.4 Mineralisation Thickness Observed in 2013 Drilling**

| Measure | True Mineralisation Thickness (m) |
|---|---|
| Mean | 0.68 |
| Maximum | 1.45 |
| Minimum | 0.50 |

The average and range of mineralised widths observed in the 2015 drilling are consistent with those observed in previous drilling conducted in the same areas.

The approximate average intercept spacing in the upper parts of the Vertikalny Central Zone is now 30 m, reducing to circa 50 m at depth.

### 10.1.2 Drilling Methods

All of the 2015 drilling was completed using diamond coring techniques, with the majority completed using Boart Longyear rigs, and the remainder using a Russian SKB 5 rig.

Figure 10.1 and Figure 10.2 show typical drill setups. The Boart Longyear rigs collar at HQ (63.5 mm) diameter and reduce to NQ (47.6 mm) at around 40 m. The Russian drill rig collars with 112 mm diameter core reducing at a depth of 6 m to 93 mm and then to 76 mm where required. The Russian rig drills dry. The Boart Longyear rigs have an established water line and drilling mud is used to maintain core recovery. Core recovery is measured and recorded by Silver Bear geologists and was found to be excellent for both the Boart Longyear and the Russian SKB 5 rig.

**Figure 10.1 Drilling at Vertikalny in 2011**

Source: Silver Bear

**Figure 10.2 Drilling at Vertikalny in November 2013**

Source: Tetra Tech

For the drilling programmes at Vertikalny, the core containing mineralised intersections were split in half by core saw or trowel as appropriate and then sampled. The weight of the core samples range from approximately 2 to 4 kg.

## 10.2 DOWN HOLE DIRECTIONAL SURVEY METHODOLOGY

For the Boart Longyear drill rig, surveys were undertaken using a Reflex 'EZ-shot'™ single shot down hole survey tool that is operated by the driller. Measurements were taken every 25 m for the first 100 m and at 50 m intervals thereafter. Readings are recorded on paper slips that are delivered to the Project geologist on a daily basis. The azimuth is recorded as magnetic and this is corrected by the appropriate declination. The measurements are recorded in the drillhole database and the drill logs. Copies are kept by the contractor.

For the Russian drill rig, down hole surveys are conducted using an inclinometer at 20 m intervals.

## 10.3 DRILLHOLE COLLAR SURVEY METHODOLOGY

The Project geologist and drill foreman co-operate to prepare all drill sites prior to the drill moves. The surveyor is directly responsible to the Project geologist.

From 2011 onwards, the previous method of chain survey was replaced by the use of Precision Point Differential Global Positioning Systems (DGPS), with the establishment of control points and a survey network. All drillhole collars and trench

locations have been re-surveyed using the DGPS. Correlation with the previous survey was very good. All surveys are reported in Universal Transverse Mercator (UTM) Wideband Global SATCOM (WGS) 84, Northern Zone 52.

## 10.4 DRILL RIG SETUP

Silver Bear geologist are responsible for setting the rig for a new hole at the correct coordinates, with the correct azimuth and dip for all holes. The azimuth and dips are checked using the drillhole orientation tool or compass clinometer. The decision to commence and stop drilling should be made in agreement with the chief geologist.

The geologist should also ensure that the core trays are ready prior to drilling, with partitions nailed in at the correct spacing according to the core diameter (HQ = 63.5 mm, NQ = 47.6 mm).

## 10.5 DRILLING, CORE HANDLING AND CORE BOX MARK-UP

Silver Bear geologists supervise the drillers to ensure that they remove the core from the core barrel and onto the core racks or directly into the core tray with sufficient care, without loss of fragments, without disrupting the order, and noting carefully the shallowest and deepest ends of the core run.

Silver Bear ensures that the core tray is marked before starting to fill it with core. The correct markings include:

- the direction of increasing depth, from the shallowest depth to the deepest, is to be shown by arrows—from left to right
- the hole number, tray number, start and end depth (from and to) are to be marked on the shallowest end of the core tray
- end depth is marked after the core tray has been filled.

**Figure 10.3 Example of Core Tray Markings**

## 10.6 GEOTECHNCIAL LOGGING OF CORE SAMPLES

Geotechnical logging is currently completed in the core logging facility at the Hogen camp. Tetra Tech recommendd that the geotechnical logging is completed at the rig side in future, to avoid artificial damage to the core being accounted for as natural fractures. The following information is recorded:

**Core size:** This refer to the type of core drilled (HQ, HQ2, NQ, NQ2, etc.).

**Total Core Recovery (TCR):** The total length of core recovered (including broken zones).

**Solid Core Recovery (SCR):** The total length of the solid core (excluding pieces of core smaller than the core diameter). However, if a single joint parallel to the core axis intersects the core piece, the pieces are counted as a solid core.

**Rock Quality Designation (RQD):** The total length of solid core cylinders of greater than 100 mm in length, expressed as a percentage.

$$\text{RQD} = \frac{\text{sum of solid core peices} > 100\text{mm in length}}{\text{core run length}} \text{ x } 100$$

Other information collected in the geotechnical log include:

- lithology
- weathering classification
- strength.

**Figure 10.4 Core Logging**

## 10.7 CORE PHOTOGRAPHY

Every box of core is photographed at the Hogen camp. Each photo is labelled with a card showing drillhole number. The photos also include a metric scale bar, and a standard colour chart.

During low-light conditions, the core boxes are illuminated by two spot lights, arranged so that there are little-to-no visible shadows in the photograph and the light conditions are the same for each photo.

The camera is positioned in the same place each time using a tripod so that the angle of the photo is perpendicular to the core box. The core is photographed wet and dry.

Photos are stored in digital format (*.jpg), on the computer in the geology office, and backed up to servers and hard drives.

**Figure 10.5 Core Photography**

**Figure 10.6 Example of How to Set up a Photograph of the Core Box**

## 10.8 GEOLOGICAL LOGGING OF CORE SAMPLES

For the 2015 campaign, the core was logged into standard hard copy logging sheets and the transcribed into excel. Tetra Tech recommends that the logging is completed directly into excel or into proprietary logging software in future to minimise the risk of transcription errors.

In general, the minimum logging interval is 0.2 m, unless specifically required to capture a significant feature (e.g. narrow mineralised vein or structure).

Lithological and oxidation logging is completed using a standardised legend of codes.

Other information recorded includes the following:

- colour
- grain/crystal size
- oxidation state
- textures
- alteration minerals
- logged by (name of geologist).

**Figure 10.7 Geological Logging of Core Samples**

## 10.1 SAMPLING DISCUSSION

### 10.1.1 VERTIKALNY

Prior to sampling, a sampling plan created by the geologists and reviewed by the chief geologist.

At many of the target areas, large sections of the drill core will contain obviously barren sedimentary rocks; therefore, sampling will be restricted to mineralised zones, with a number of waste samples taken either side of the mineralisation to ensure that full intercepts are sampled and that contacts are defined in the subsequent assay data.

The zones for sampling are selected based upon the lithological logging, with reference to the following important observations:

- visible alteration
- sulphide minerals
- breccia textures
- Intrusive (dyke) intervals
- faulted or disrupted zones.

Standard sample lengths are 1 m, but are reduced to a minimum of 0.1 m to ensure that samples do not cross lithological boundaries.

A minimum of two, 1 m samples of visually non-mineralised material are taken above and below the mineralised intercepts. If the angle of intercept of the mineralised zone is acute (less than 45° to the core axis) then additional 'barren' samples are selected.

Visually un-mineralised inter-burden between mineralised samples should be continuously sampled in lengths of up to 1 m, if the interval between mineralised zones is less than 5 m.

On the porphivory deposit, the mineralised material is more difficult to identify visually; therefore, continuous sampling is undertaken from the start to end of the drillhole. As with other deposits, the standard sample length is 1 m, but is reduced to a minimum of 0.1 m to honour lithological contacts.

Sampling is recorded on the sampling register. Sample numbers are continuous and consistent with the sample tags. Sample tags are stapled to the core box in the relevant location, with the duplicate sample tag retained. The sample register lists the sample numbers, the intended analytical techniques and mass of sample(s). It also shows which samples should have a duplicate sample weighed and bagged, and which sample numbers to be assigned to blanks and standards.

Samples are indicated by marking the end of each sample with a black marker on both the core and on the core box divider walls. The intervals are also recorded on the sample tags that are stapled to the core box.

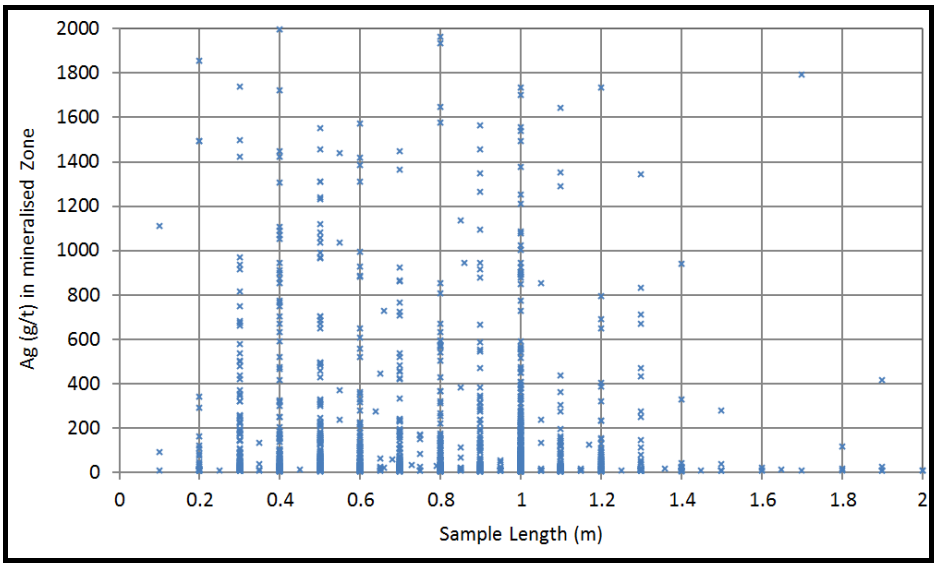
Samples marked for cutting are marked with a ruled line marking the cutting line. This cutting line bisects the symmetry present in the mineralisation (e.g. dip of structures or ore zone boundaries) or if this is absent, is drawn along the axis of bedding symmetry of the surrounding host rocks.

Samples are generally cut with a diamond saw. Where the core is too fragile or broken for cutting, no line is drawn and half the width of the channel holding the core in the core tray is to be taken with a spatula.

Following cutting, the core box then is to be taken to the sample preparation room where the core samples are taken, placed in bags, dried and weighed. The geologist manages the sample preparation team to ensure that sampling is undertaken in accordance with the sample register.

Figure 10.8 illustrates that there is no correlation between sample length and grade.

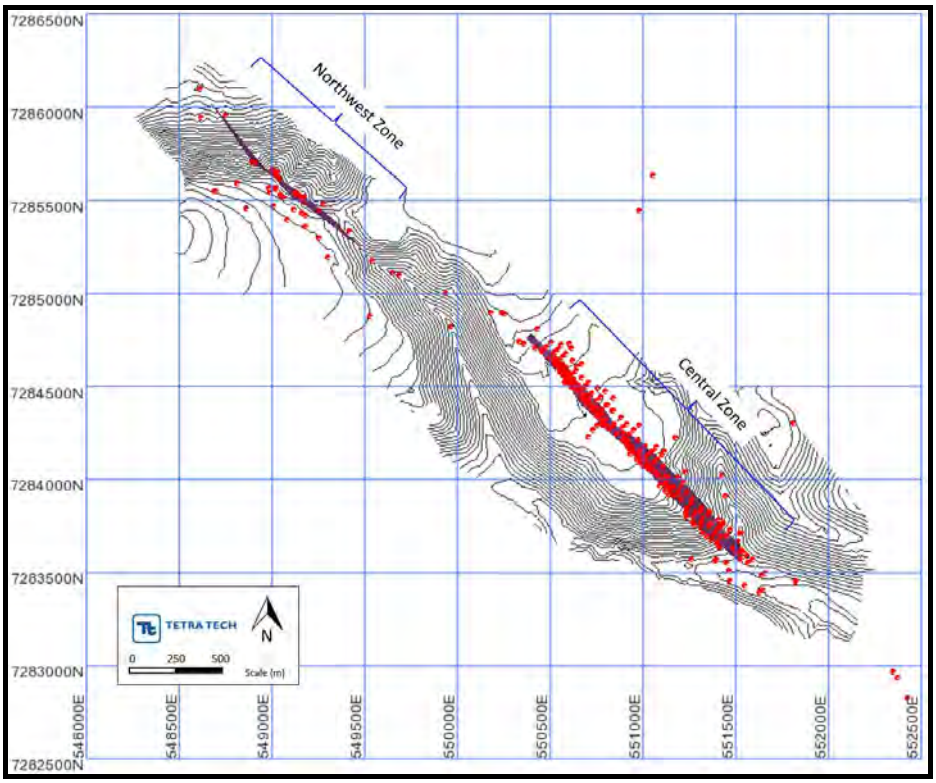
**Figure 10.8 Silver Grade vs. Sampled Length**




Source: Tetra Tech

The Vertikalny (vein) structure can be identified during logging, therefore any intersection of the structure may contain a variety of lower and higher grade intervals. During the 2011 and 2012 campaigns, sampling was undertaken according to a nominal 1 m standard sample length with non-mineralised material sampled at either end of the mineralised intersections. From 2013 onwards, the sampling was based upon logging intervals, however, systematic 1 m samples of non-mineralised material was sampled at either end of the mineralised intersections as in previous campaigns.

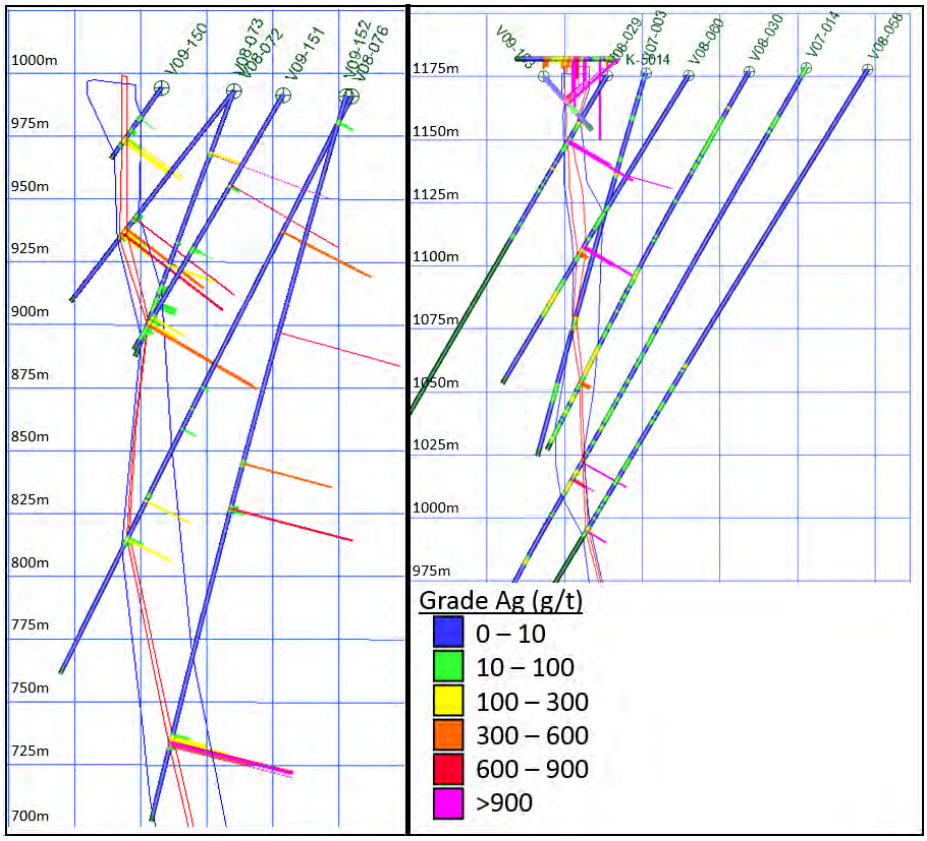
**Figure 10.9 Drillhole Collar Locations and Mineralisation**




Source: Tetra Tech

Figure 10.10 presents a representative drill section through the Central Zone of the Vertikalny deposit.

**Figure 10.10 Section through the Central Zone of Vertikalny**




Source: Tetra Tech

The Vertikalny mineralised zone is dominated by a series of brecciation events and probable subsequent fault movement within the host rocks. As a result, the presentation of the mineralised zone varies from solid cylinders of core through to highly broken, soft gouge type material.

The core recovery is generally very good, averaging approximately 95%. Decreased recovery has occurred in a small number of mineralised intervals. Drilling muds and polymers were used to enhance recovery. There is no correlation between recovery and silver grade.

## 10.2 TETRA TECH OPINION

Some inconsistencies were noted within the drillhole database and procedures and systems are being put in place to circumvent similar occurrences in future. In Tetra Tech's opinion, the inconsistencies do not represent a material risk to the robustness of the Mineral Resource estimate.

Tetra Tech is of the opinion that the drilling has generally been completed using methods and procedures that are consistent with recognised industry practices and that the data is adequate for Mineral Resource estimation.

# 11.0 SAMPLE PREPARATION, ANALYSES AND SECURITY

This section summarises the sampling and sample preparation methodology adopted by Silver Bear during their various exploration programmes since 2007. Prior to 2007, the sample preparation, analyses, and security was conducted according to Russian State Reserve Committee (GKZ) standards.

The general approaches and methodologies are consistent for all of the targets across the Property, with the exception of specific components which are described separately for each area in Sections 11.1.4 and 11.1.5.

Training of Russian geologists and support staff in sampling procedures is carried out by Silver Bear.

## 11.1 SAMPLE PREPARATION AND ANALYSES

Upon completion of logging and sampling, paperwork outlining the regime for analysis was prepared from the geological log. Silver Bear operates its own sample preparation laboratory where samples are crushed and milled (Figure 11.1).

**Figure 11.1 Crushing Equipment in Silver Bear's On-site Sample Preparation Facilities**

Source: Tetra Tech

Samples are crushed and milled to greater than 85% passing 1 mm, before quartering, to produce a 1 kg sample. Final milling is carried out at the assaying laboratory ALS Chemex in Chita, Russia, where the material is reduced to 85%

passing 75 µm. This sizing is based on industry standard sizing for homogeneity in the preparation of the sample aliquot.

Sample trays are vacuum cleaned post jaw crushing. The jaw crusher operator clears all sample material from the crusher and brushes off the crusher apron and top of the jaws. After the jaw crushing, the sample tray is thoroughly brushed out. No crushing of samples was conducted during the site visit; therefore, no vacuuming of this tray was observed. Blank material is run through the crushers after every 10 samples, or after every sample if designated for fire assay in order to wash through the equipment to help prevent cross contamination of sample. Currently, there is no compressed air available to blow out dust from the crushers. It is strongly recommended that an air compressor be introduced to thoroughly clean all sample preparation equipment.

The crushed sample is systematically mixed on a metal-surfaced table using flat blades, and then manually quartered using a steel quadrant device (Figure 11.2).

**Figure 11.2 Sample Splitting in Silver Bear's On-site Sample Preparation Facilities**

Source: Tetra Tech

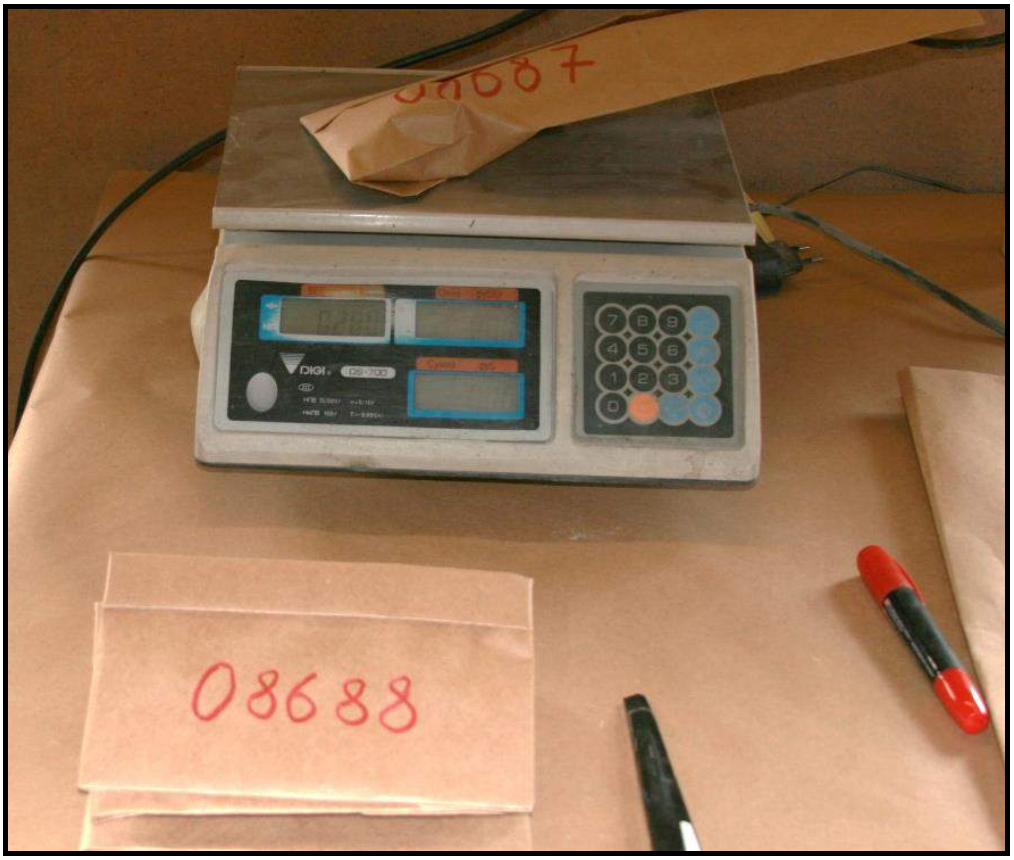
The operator then takes an approximately equal scoop from each quarter to fill the required sample bags. The sample bags are weighed by the operator to ensure that a sample of more than 100 g of sample is taken, greater than the 50 g typically required for assay plus spare pulp. The remaining pulp sample is retained if the sample is designated for fire assay so that in addition to the duplicates additional assay can be run from the homogenised sample if required. Coarse reject material is also retained as shown in Figure 11.3. The table is thoroughly brushed off between samples. Compressed air is also recommended to clean the table for this stage of preparation.

**Figure 11.3 Coarse Reject Store Shed**

Source: Tetra Tech

The samples are sealed and accurately weighed, and the weight is recorded on the sampling list (Figure 11.4). Samples for analysis are boxed and sealed, usually in batches by drillhole, for despatch to the laboratory concerned.

**Figure 11.4 Weighing Scales in Silver Bear's On-site Sample Preparation Facilities**




Source: Tetra Tech

Boxed samples are checked against the sample list and a despatch note. The exact sequence of sample numbers is listed as to the order in which the samples are to be processed at the laboratory. This includes how the samples are to be processed, even if the numbers are not sequential. Chain of custody documentation and a copy of the instructions is sent to the laboratory.

### 11.1.1 LABORATORIES

Prior to 2011, analysis was carried out at Russian certified Chemical Laboratory of the State Enterprise Aldangeologiya (Aldan Lab), located in Yakutia, Russia.

Analysis for 2012, 2013, 2014, and 2015 campaigns were completed by International Organization for Standardization (ISO)/International Electrotechnical Commission (IEC) 17025 accredited laboratory ALS Chemex in Chita, Russia.

Both laboratories are internationally accredited and wholly-independent of Silver Bear.

### 11.1.2 ASSAYING

Prior to 2011, the samples sent for fire assay were analysed in duplicate for silver. All samples were sent for fire assay. Samples with significant silver grades, determined from spectral analysis were also analysed for silver, copper, lead, and zinc using atomic absorption (AA). Samples sent for spectral analysis were analysed for 36 elements, including tin, lithium, titanium, cobalt, mercury, and vanadium.

From 2011 onwards, analyses were completed using a four acid sample digestion of 0.25 g, followed by inductively coupled plasma (ICP) finish and reporting of 33 elements (laboratory code ME-ICP62). Where values of silver, lead or zinc exceeded the respective upper detection limits, further four acid digestion analyses were carried out of 0.4 g, followed by ICP finish (laboratory code ME-OG62). Where values of silver exceeded the upper detection limit for ME-OG62 (1,500 g/t), a 50 g sample was taken for fire assay analyses with a gravimetric finish (laboratory code Ag-GRA22).

A selection of the samples was identified by the Prognoz geologists for gold assaying. This was undertaken via fire assaying with an AA finish using a 50 g sample (laboratory code Au-AA24).

Retained samples (duplicates and rejects) are boxed by drillhole number and stored in a locked container at the Endybal site. Analytical results are received electronically and updated in the drillhole database.

Assay certificates are submitted in electronic and hard copy form to the Project geologists.

### 11.1.3 QUALITY ASSURANCE/QUALITY CONTROL

Since 2007, Silver Bear has employed an industry standard quality assurance (QA)/quality control (QC) programme, which includes chain of custody protocols, as well as systematic submittals of standards, duplicates, and blank samples into the flow of samples sent for assaying. Prior to 2007, the sampling procedures were

consistent with the requirements of the Russian GKZ system. No sample results prior to 2007 have been used in estimating the current Mineral Resource for Verticalny, due to the lack of data validation and QA/QC.

A continuous sample numbering system has been adopted by Silver Bear, which does not differentiate control samples so that the QA/QC samples are sequential in the packing list in order that they not be recognised by the lab. Sample numbering is defined by the geologist for each hole as part of the sampling plan. ALS Chemex also reported its own standards, duplicates, and blanks as part of their own QA/QC protocol.

### 11.1.4 VERTIKALNY QA/QC

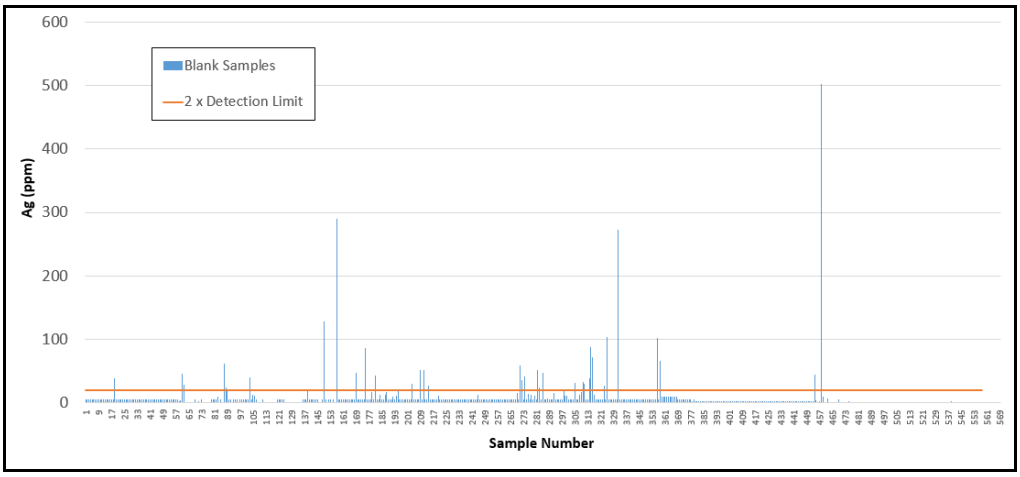
Since 2007, the Vertikalny exploration programmes have included the submission of 1,654 QA/QC samples, along with 13,892 regular samples. For the purposes of QA/QC and Resource Estimation, Spectral Analysis (SA) results have not been included due to their unreliability in this study.

#### *VERTIKALNY BLANKS*

Blank samples are created from local non-mineralised rock and processed in the on-site sample preparation laboratory. Blank material is stored on the ground outside of the sample preparation laboratory.

Blank material is broken up with a hammer and placed into a sample bag. Blank samples are then inserted in numerical order into the sequence for preparation. Since 2007, 558 blank samples have been analysed at Vertikalny (Figure 11.5). Of those 558 samples, 37 were above two times detection limit of which 10 are significant .The blank failure is not considered material to the Estimate as the majority of the recorded values are significantly lower than any economic mineralisation.

**Figure 11.5 Blanks Chart for Vertikalny Exploration Data**




Further analysis has shown that the performance of the blanks was poorer within higher-grade intersections (greater than 100 g/t silver), which could indicate that there was some contamination. It is noted, however, that the number of blanks submitted within the higher-grade intersections is low; therefore, statistical significance cannot be established.

Further analysis was carried out to determine whether blank sample failure was due to contamination, or because of substandard original blank material. The analysis was completed by comparing the poorly performing blanks against the three samples that preceded them through the sample preparation process. No obvious indication was found that could link the poorly performing blanks to the samples that were processed immediately before. Therefore, it was concluded that the blank material probably contained minor mineralisation, and it is recommended that the material used for blank samples is re-examined or replaced by material known not to carry any target mineralisation. Commercially-sourced certified blank material would be recommended to eliminate any possibility of minor mineralisation. It is also recommended that the sample preparation apparatus is flushed with a quartz sand wash between samples.

Blank samples were also independently assessed for each campaign, and were found to be well within acceptable limits.

### *VERTIKALNY STANDARDS*

Since 2007, a total of 563 standard reference samples have been submitted for analysis as part of the Vertikalny exploration. The standard reference materials (SRMs) were sourced from Geostats Pty Ltd, who are based in Perth.

The SRMs used and the number of times they were submitted are outlined in Table 11.1, with all SRM plots shown below.

**Table 11.1 SRMs used in the Vertikalny Exploration**

| Standard | No. of Submissions | Ag Value (g/t) | Standard Deviation Ag | Number of Failures* | Pass Rate (%) |
|---|---|---|---|---|---|
| GBM 906-6 | 194 | 389.7 | 21.1 | 6 | 96.91 |
| GBM 303-1 | 11 | 1419.6 | 73.5 | 3 | 72.73 |
| GBM 909-11 | 25 | 25.5 | 1.7 | 4 | 84 |
| GBM 909-13 | 25 | 127.3 | 6.8 | 4 | 84 |
| GBM 310-16 | 43 | 314.3 | 14.9 | 3 | 93.02 |
| GBM 997-4 | 116 | 287.9 | 38.2 | 4 | 96.55 |
| GBM 998-9 | 133 | 101.2 | 4.8 | 10 | 92.48 |
| GBM 913-13 | 16 | 74.1 | 3.9 | 0 | 100 |
| **Total** | **563** | - | - | **35** | - |

Note: *failure defined as assay result falling outside of two standard deviations.

Good standard performance is reported for the following standards:

- GBM997-4.
- GBM906-6.
- GBM310-16.
- GBM998-9.

No failures were reported for the following standards:

- GBM 913-13.

**Figure 11.6 GBM913-13 Chart for Vertikalny Exploration Data**

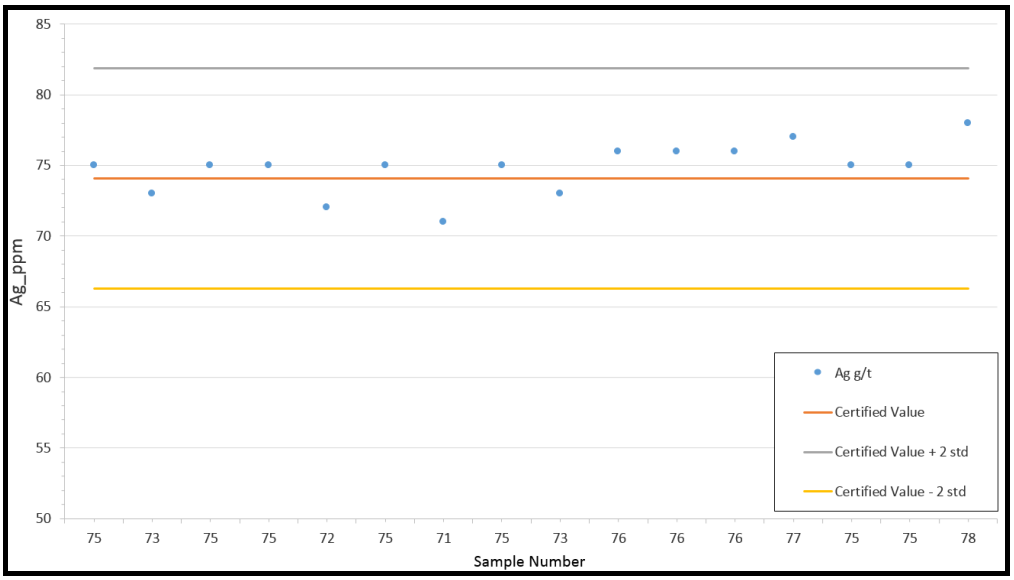



**Figure 11.7 GBM997-4 Chart for Vertikalny Exploration Data**

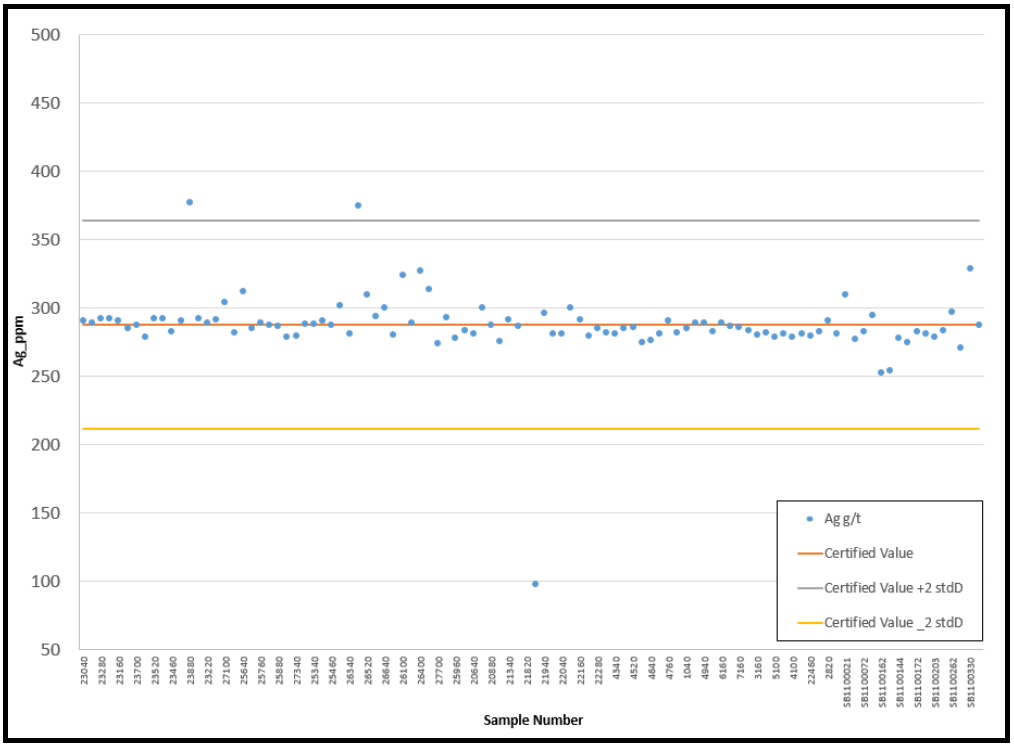


**Figure 11.8 GBM906-6 Chart for Vertikalny Exploration Data**

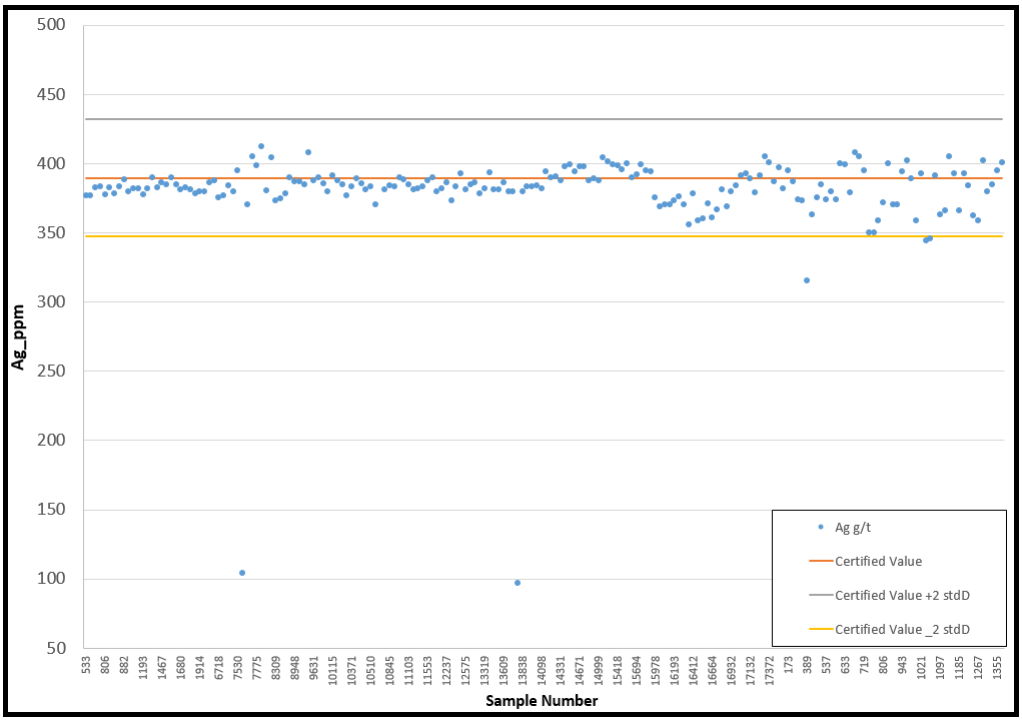
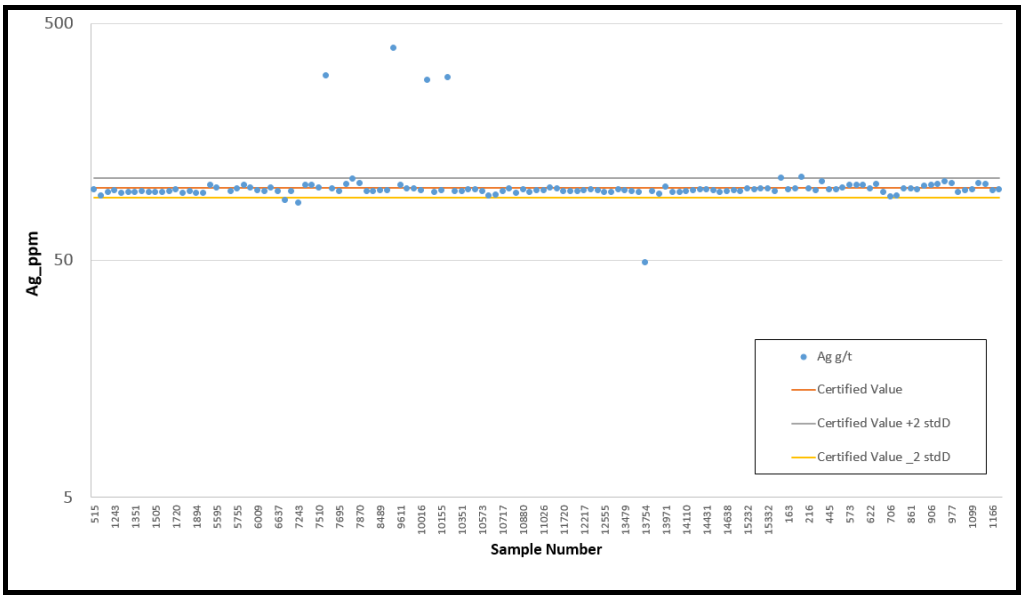
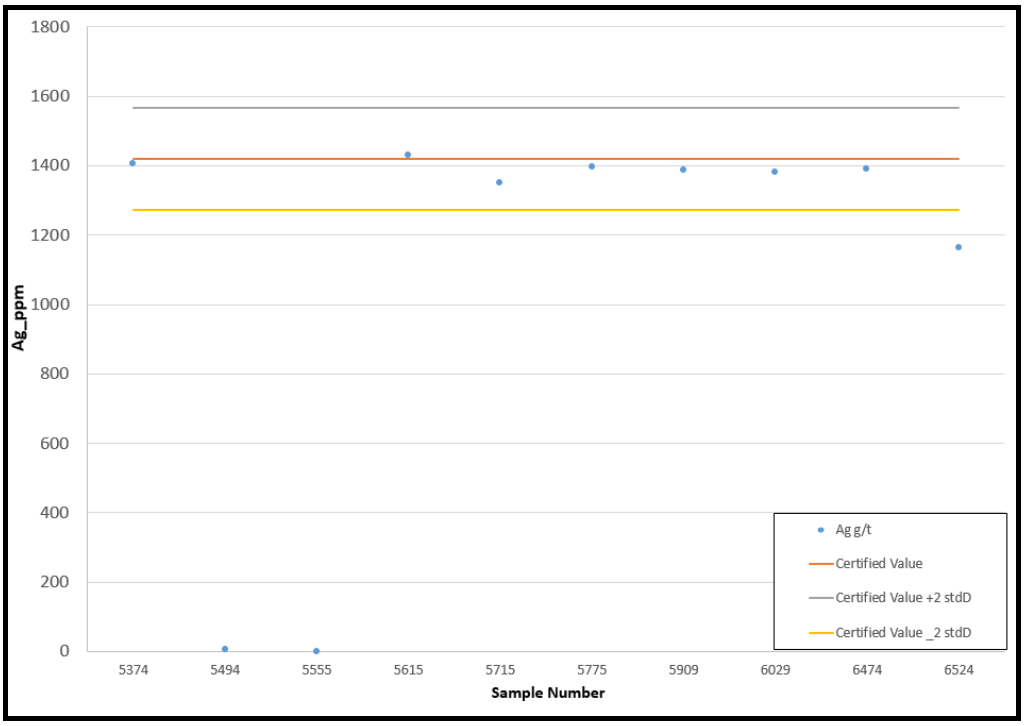



**Figure 11.9 GBM998-9 Chart for Vertikalny Exploration Data**




It is noted that the only high-grade silver standards used was GBM303-1, and this standard was only submitted eleven times (Figure 11.10). The GBM303-1 plot highlights two outliers which may have been miss labelled due to the near detection limit values recorded.

**Figure 11.10 GBM303-1 Chart for Vertikalny Exploration Data**




Tetra Tech note that standard performance across the 2012 campaign was poor, leading to outliers shown in GBM310-16, GBM909-13 and GBM909-11 (Figure 11.11 to Figure 11.13). These outliers are near to the silver detection limit so could have been miss labelled as blank material or another factor. Interrogation of the assay results across the five 2012 drill holes shows the data is all below cut-off grade. Thus there would be little impact on the overall Vertikalny resource as standard performance across these SRMs is adequate.

**Figure 11.11 GBM310-16 Chart for Vertikalny Exploration Data**

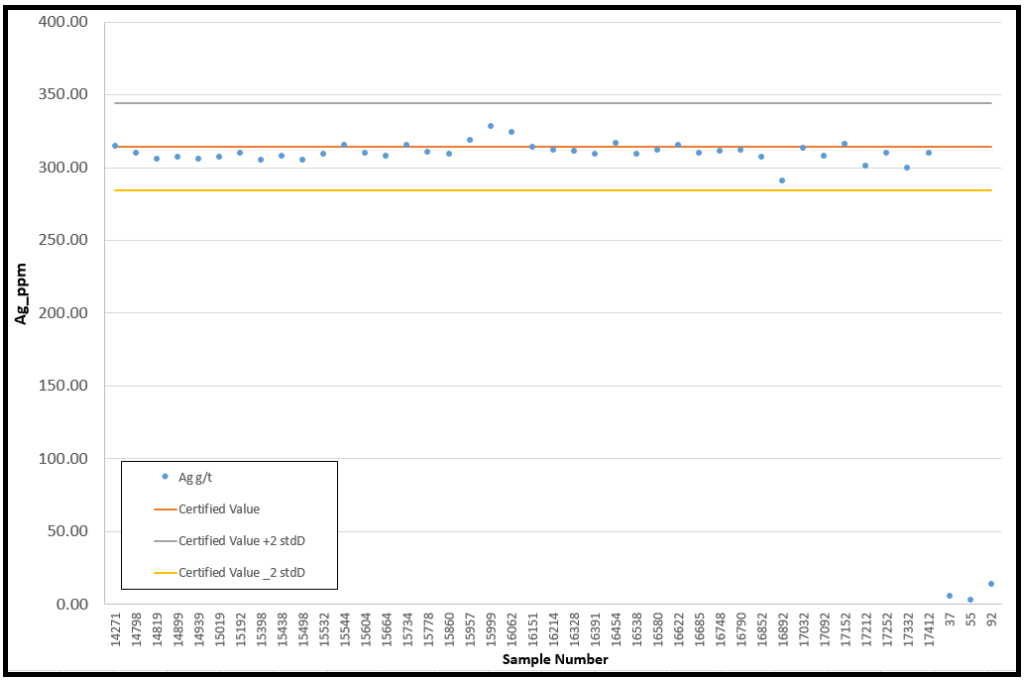



**Figure 11.12 GBM909-13 Chart for Vertikalny Exploration Data**

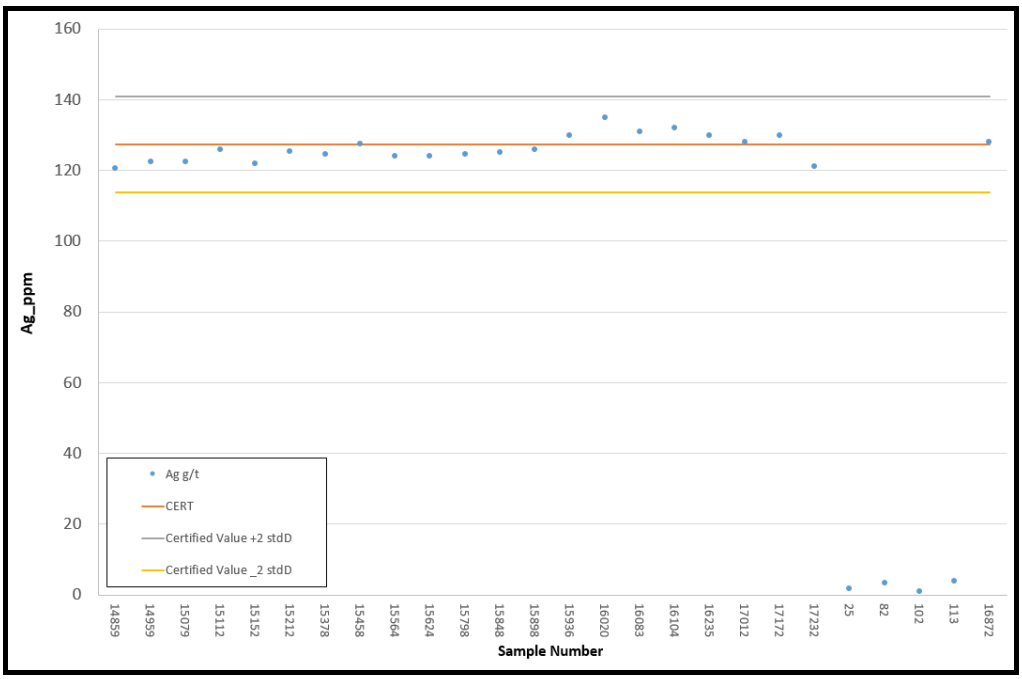
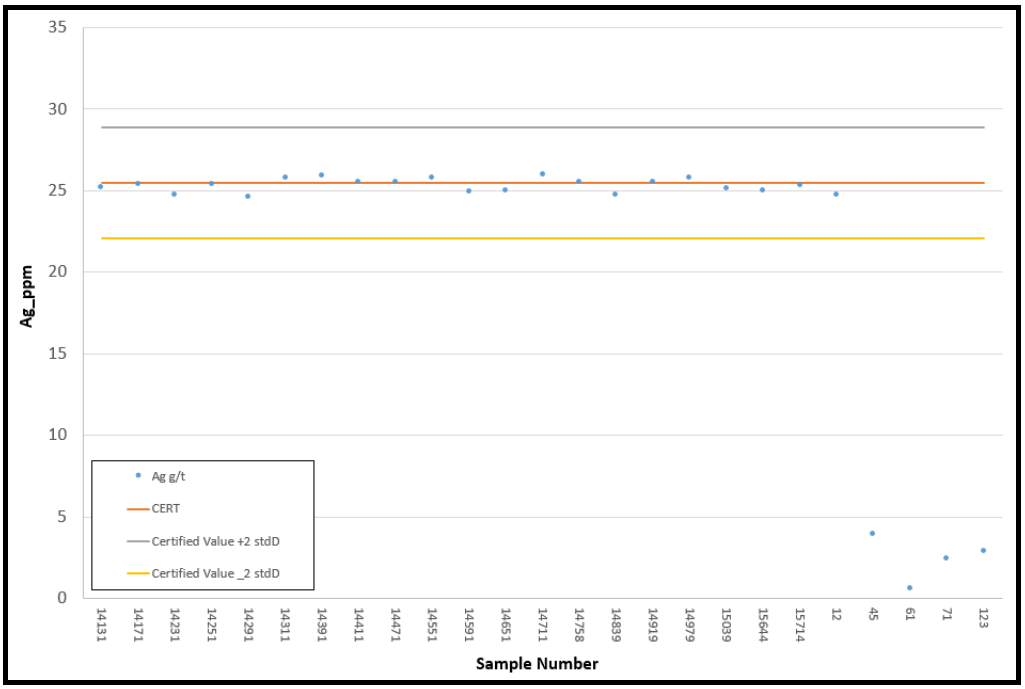


**Figure 11.13 GBM909-11 Chart for Vertikalny Exploration Data**

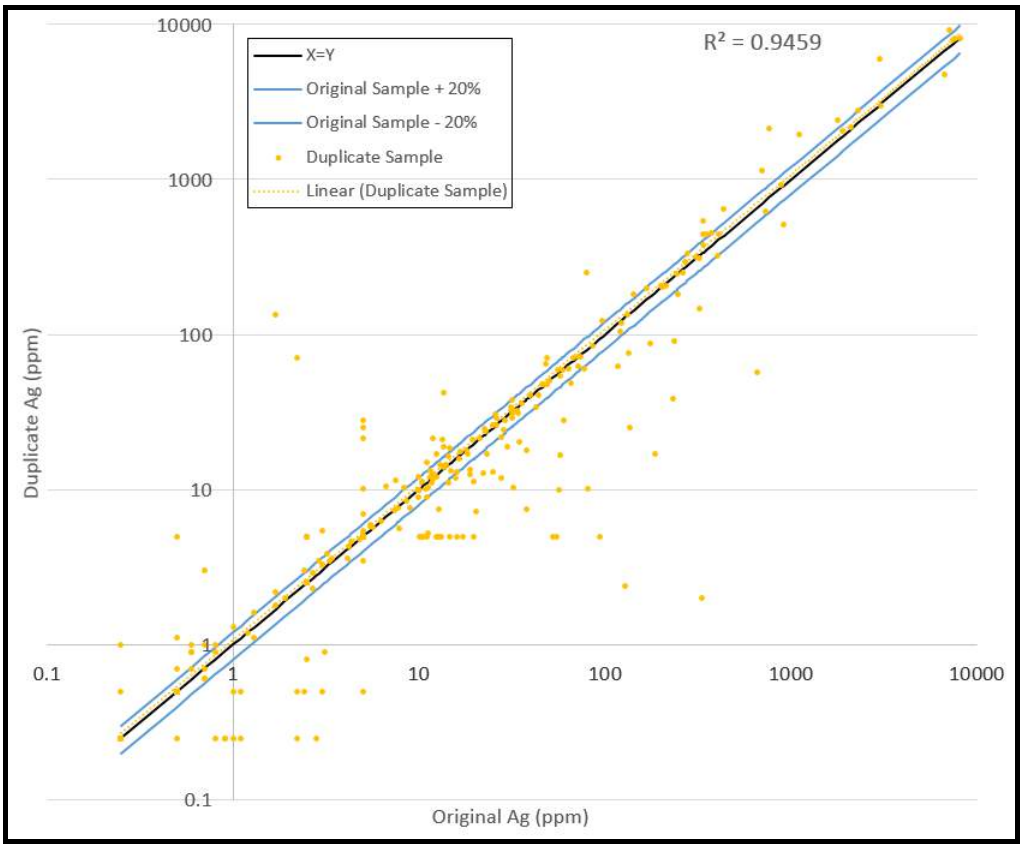



Standard reference samples were independently assessed for each campaign, and were found to be well within acceptable limits.

### *Project Duplicates*

Between 2007 and 2015, 533 duplicates were submitted as part of the Vertikalny exploration programs. The data ranges from less than 10 g/t through to greater than 8,000 g/t. Overall, the data show good levels of precision and repeatability, with a slope of regression of 0.95. The data suggest an improvement as the grade increases. Many of the duplicates falling outside of ±20% difference envelope are at lower grades less than 100 g/t. There are also indications of duplicate swapping within the 7 to 50 g/t range (Figure 11.14) where duplicates were used in error and have had the results recorded as a different sample.

**Figure 11.14 Duplicate Chart for Vertikalny Exploration Data**




Field duplicates have also been examined on a campaign by campaign basis, and show similar results with repect to precision and repeatability.

ALS Chemex also submit laboratoroy duplicates as part of their internal QA/QC programme. The analysis of the laboratory duplicate data shows good compliance, with excellent precision and repeatbility.

### 11.1.5 NIZHNY ENDYBAL QA/QC

The Nizhny Endybal exploration campaigns were completed during the 2005, 2011, and 2012 field seasons. The QA/QC data associated with the 2005 campaign are no longer available; however, drillholes completed during the 2011 and 2012 campaigns were twinned with 2005 holes to validate the information. The 2005, 2011, and 2012 drillhole data was used in estimating the current Inferred Mineral Resource. As part of the 2011/2012 exploration campaigns 607 QA/QC samples were submitted, along with 2,752 regular samples.

#### *NIZHNY ENDYBAL BLANKS*

Blank samples are created from local non-mineralised rock and processed in the on-site sample preparation laboratory. Blank material is stored on the ground outside of the sample preparation laboratory.

Blank material was broken up with a hammer and placed into a sample bag. Blank samples were then inserted in numerical order into the sequence for preparation.

During the 2011/2012, 107 blank samples were analysed at Nizhny Endybal. Of those 107 samples, 3 were found to be out of range.

The three failures presented low silver grades of 1.9, 3.3, and 6.2 g/t. Overall, the blank performance was found to be acceptable.

Blank samples have also been independently assessed for each campaign, and were found to be well within acceptable limits.

### *Nizhny Endybal Standards*

As part of the Nizhny Endybal exploration during 2011 and 2012, 193 standards were submitted for analysis. The standard reference materials used and the number of times they were submitted are outlined in Table 11.2.

**Table 11.2 SRMs used in the Nizhny Endybal Exploration during 2011 and 2012**

| Standard | No. of Submissions | Ag Value (g/t) | Standard Deviation Ag | Number of Failures* | Failure Rate (%) |
|---|---|---|---|---|---|
| GBM 906-6 | 81 | 389.7 | 21.1 | 5 | 6 |
| GBM 909-11 | 46 | 25.5 | 1.7 | 0 | 0 |
| GBM 997-4 | 2 | 287.9 | 38.2 | 0 | 0 |
| GBM 998-9 | 64 | 101.2 | 4.8 | 2 | 3 |
| Total | 193 | - | - | 7 | 4 |

Note: *failure defined as assay result falling outside of two standard deviations.

It is noted that the overall average silver grades are lower at Nizhny Endybal than Vertikalny, and that the range of standard samples used are appropriate.

No failures were reported for the following standards:

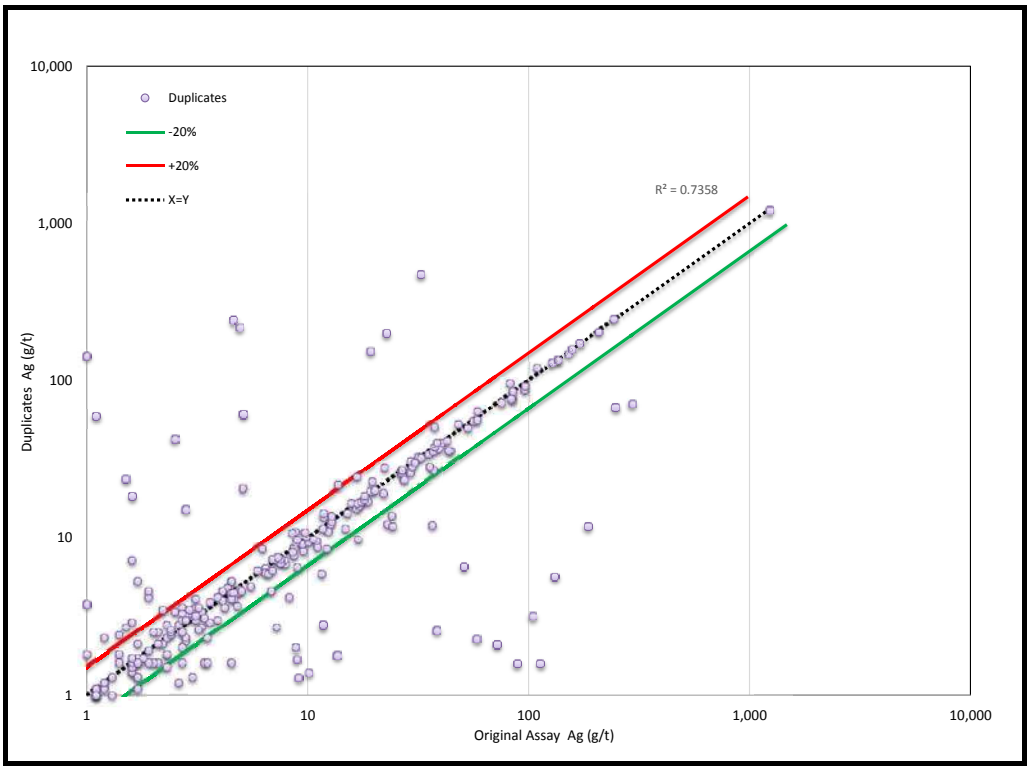
- GBM 909-11
- GBM 997-4.

Standard samples have also been independently assessed for each campaign and were found to be well within acceptable limits.

### *Project Duplicates*

As part of the Nizhny Endybal exploration campaigns in 2011 and 2012, 307 duplicates were submitted. The data ranges from less than 10 g/t through to greater than 1,200 g/t. Overall, the data shows adequate levels of precision and repeatability, with a slope of regression of 0.74 (Figure 11.15).

**Figure 11.15 Nizhny Endybal Duplicate Chart**




Field duplicates have also been examined on a campaign by campaign basis and show similar results with repect to precision and repeatability.

ALS Chemex also submit laboratoroy duplicates as part of their internal QA/QC programme. The analysis of the laboratory duplicate data shows good compliance, with excellent precision and repeatbility.

### 11.1.6 Mangazeisky North Deposits QA/QC

Presented below is a summary of the QA/QC programme adopted for the samples collected as part of the 2015 Mangazeisky North drilling programme. QA/QC associated with the 2013/14 campaigns are disclosed fully in Tetra Tech's 2015 Technical Report (Tetra Tech 2015b).

#### *Blanks*

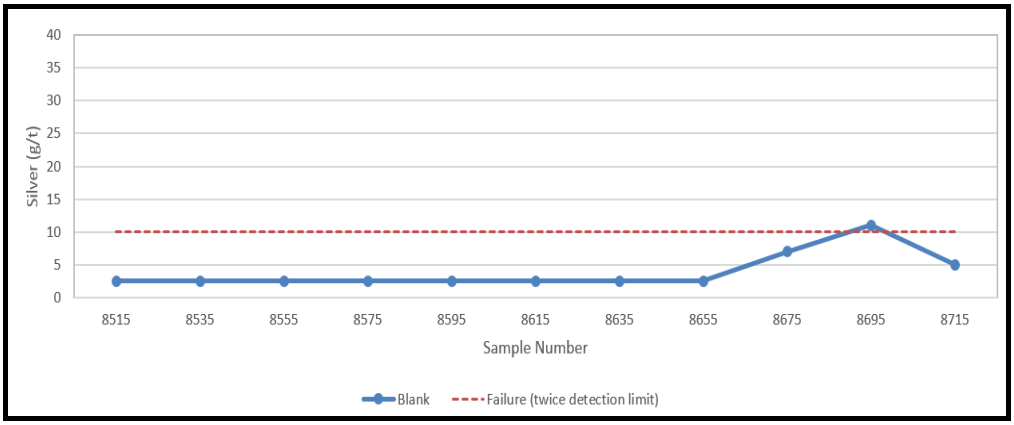
Blanks have been inserted into the sample stream every 20th sample.

Blank samples are created from local non-mineralised rock and processed in the on-site sample preparation laboratory. Blank material is stored on the ground outside of the sample preparation facility.

Tetra Tech considers the QA/QC blank analysis programme to be adequate for the level of study. One blank failed for silver grades of a total of 11 analyses during 2015, which is a 9% failure rate. The failed sample has a low grade (11 ppm) and may be due to minor mineralisation, rather than any failure relating to poor practice. Tetra Tech recommends sourcing a true blank material to reduce the failure rate to zero.

Figure 11.16 shows the Tetra Tech blank analysis for silver grades.

**Figure 11.16 Blank Sample Performance**




Source: Tetra Tech

### *STANDARDS*

Standard reference materials are inserted on site into the sample stream in every batch every 20 samples. The standard reference materials were purchased from Geostats Pty Ltd.

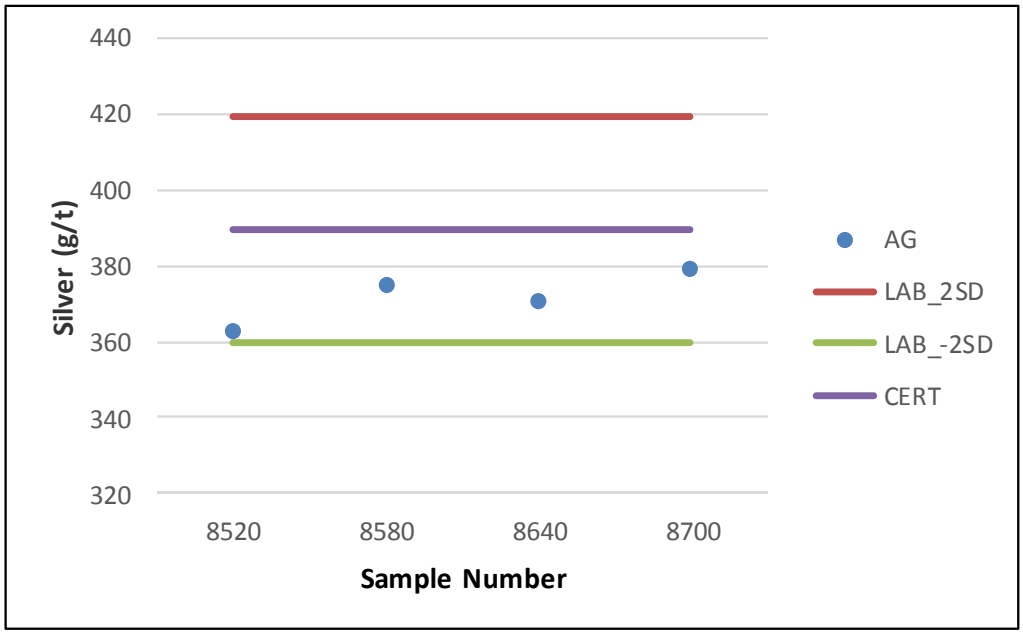
Three standard reference materials were used for the 2015 exploration campaign, GBM906-6, GBM909-13 and GBM310-16. GBM906-6 and GBM909-13 performed well, with all of the results being within 2 standard deviations of the stated mean.

The three samples of GBM310-16 submitted to the laboratory failed to return results within two standard deviations of the stated mean (Table 11.3). The results were consistently 30% lower than the expected value. The failure was queried with the laboratory (ALS), who commented that the failure was due to the standard having very high sulphur concentrations, which meant that the ICP analysis was not able to detect all of the contained silver. ALS commented that the precision and repeatability of their testing was within acceptable limits based upon internal duplicates. The sulphur content of GBM310-16 is significantly high than the content of the Mangazeisky mineralisation and therefore is not representative of the deposit. ICP is an appropriate method for the mineralisation, therefore GBM310-16 will be replaced by a different standard (with lower sulphur) for future campaigns.

**Table 11.3 Silver Standard Performance**

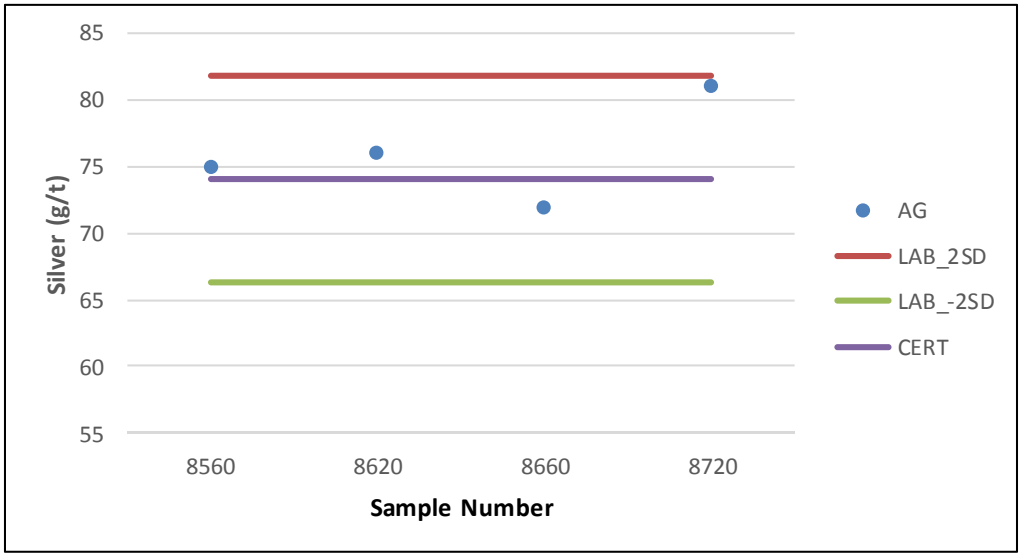
| Name | Count | Certified Value | Ag Mean (g/t) | Ag Lab Standard Deviation (g/t) | Difference (%) | Ag Fail >2 Standard Deviation |
|---|---|---|---|---|---|---|
| GBM906-6 | 4 | 389.7 | 372 | 14.9 | -0.05 | 0 |
| GBM909-13 | 4 | 74.1 | 76.0 | 3.9 | -3.00 | 0 |
| GBM310-16 | 3 | 314.3 | 217.33 | 14.9 | -0.31 | 3 |

**Figure 11.17 Standard GBM906-6 Performance**



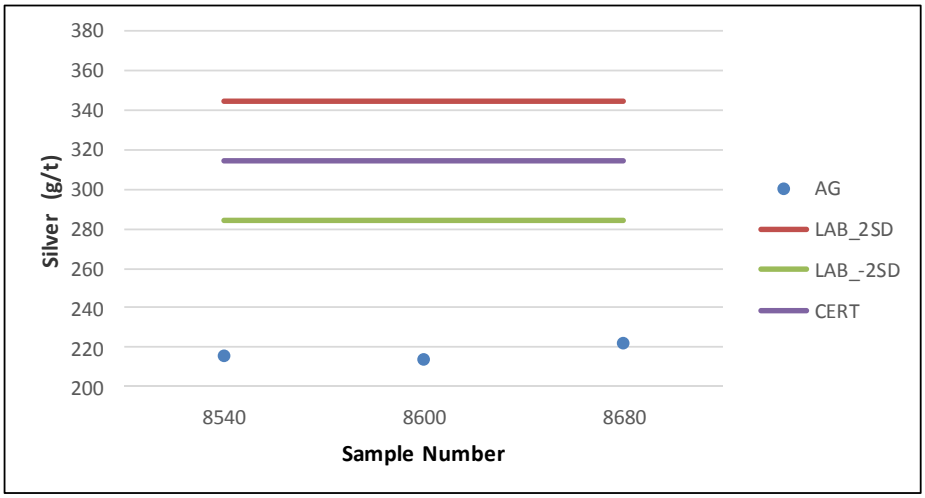

Source: Tetra Tech

**Figure 11.18 Standard GBM909-13 Performance**




Source: Tetra Tech

**Figure 11.19 Standard GBM310-16 Performance**



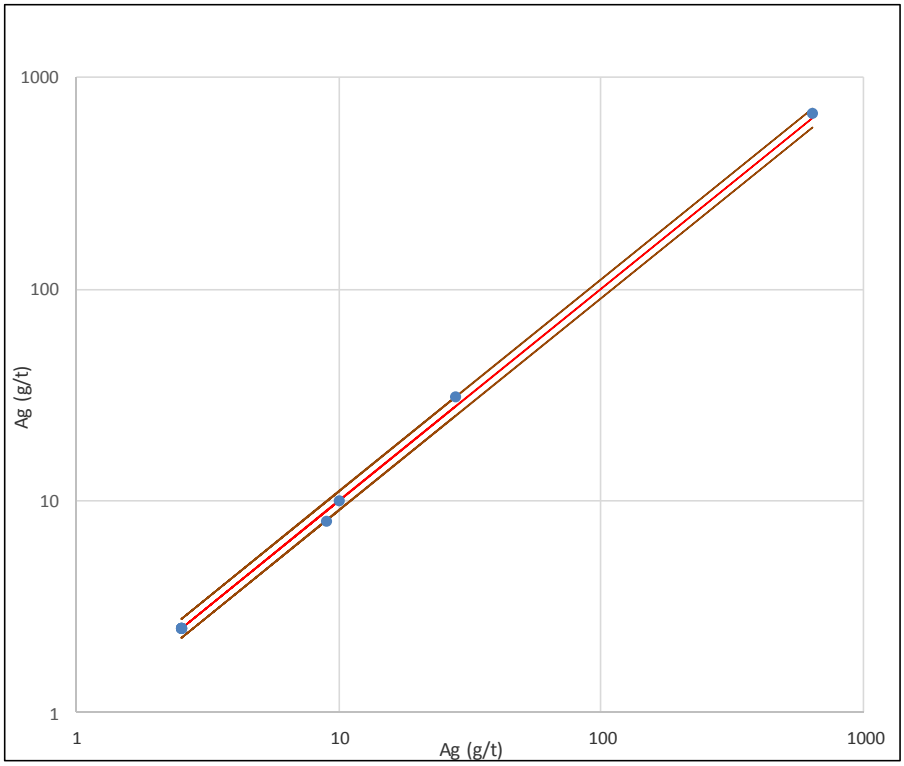

Source: Tetra Tech

In the context of the previous good standard performance, Tetra Tech considers the standard assessment for the Project has been robust. Tetra Tech recommend the replacement of GBM310-16 with a lower sulphur standard and a continuing of the monitoring of the standard performance over time to identify any drift.

### *Duplicates*

Duplicate samples were inserted into the sample stream every 20 samples from the pulps. No field duplicates were analysed. In total 11 duplicates were assessed during 2015.

**Figure 11.20 Pulp Duplicate Performance (Log Scale)**




Source: Tetra Tech

Duplicates performed well with no failures.

Tetra Tech recommends changing the sampling of duplicates to focus on the mineralised intersections, where duplicate analyses will be more meaningful than analysing the waste that is inevitable on a set 20 sample interval.

## 11.2 SECURITY

Silver Bear has implemented adequate systems in relation to sample security during transport and on-site storage and handling, with satisfactory chain of custody documentation and procedures.

Database security is maintained through a limited number of personnel having access to the database. One staff member is responsible for the transfer of assay results to the drillhole database in the office in Yakutsk. The database is password protected on a backed-up network drive and is verified by the chief geologist for the Project.

## 11.3 TETRA TECH OPINION

Tetra Tech considers that the QA/QC programmes for drill core are suitable to support Mineral Resource estimation. The number of samples assessed for QA/QC purposes is to industry best practice. Tetra Tech recommends focusing the QA/QC programme toward the mineralised intersections in future campaigns. Tetra Tech further recommends that core sample duplicates should be made by splitting two samples from the initial crushing cycle, as well as by splitting two samples from the pulped material.

The trenching campaign completed in 2013 did not contain QA/QC samples, it is recommended that the trenches are re-sampled with the inclusion of QA/QC samples.

# 12.0 DATA VERIFICATION

## 12.1 TETRA TECH SITE VISIT

Tetra Tech has conducted several site inspections in recent years. The most recent site visit to the property was performed by Mr. Robert Davies, CGeol, EurGeol, Senior Resource Geologist for Tetra Tech in July 2016.

### 12.1.1 TETRA TECH AUGUST 2015 SITE VISIT

Mr. Davies conducted a site visit to the Property between 26th June and 9th July.2016. At the time of the visit, drilling was being completed on Mangazeisky North deposit. No active drilling or exploration was taking place in the Vertikalny area. The visit included an inspection of the Mangazeisky North and South, Porfirovy, Vertikalny, Sterzhnevoy, Vostotchny and Kis Kuel deposits.

The site visit also included an inspection of the base camp, core logging and core storage facilities, drill core sampling preparation and sample rejects storage facilities.

Mr. Davies was accompanied on the site visit by the following personnel:

- Sergey Kraushkin, Chief Geologist for Prognoz
- Sergey Ivanov, Translator for Prognoz
- Vladimir Stepanov, Exploration Geologist for Prognoz.

### 12.1.2 DRILLHOLE LOCATIONS

The locations of several drillholes were measured for comparison with coordinates provided by Silver Bear. Drillhole collar locations were verified using a hand-held global positioning system (GPS); Garmin™ GPSmap 60Cx. The collar locations were found to be consistent with the drillhole database survey data, given GPS unit accuracy, the X and Y coordinates are within ±6 m in X and Y (Table 12.1).

Drillholes were marked by logs stuck into the drillhole. The logs were marked with an aluminium tag bearing the drillhole number.

At the time of the site visit, an infill drill programme was in progress on the Vertikalny deposit, with one drill rig in operation. Drill sites were left tidy and clear of debris.

**Table 12.1 Verified Drillhole Collar Coordinates (UTM WGS 84)**

| Drillhole/ Trench Name | Silver Bear X (m) | Silver Bear Y (m) | Tetra Tech X (m) | Tetra Tech Y (m) | Δ X (m) | Δ Y (m) |
|---|---|---|---|---|---|---|
| Mangazeisky North | | | | | | |
| MN14-13 | 552398 | 7290384 | 552402.5 | 7290387.9 | 4.5 | 3.9 |
| MN14-14 | 552424 | 7290400 | 552425.8 | 7290404.5 | 1.8 | 4.5 |
| MN14-17 | 552454 | 7290366 | 552454.1 | 7290368.2 | 0.1 | 2.2 |
| MN14-18 | 552477 | 7290368 | 552476.5 | 7290372.1 | -0.5 | 4.1 |
| MN14-24 | 552450 | 7290240 | 552449.6 | 7290243.2 | -0.4 | 3.2 |
| MN14-27 | 552474 | 7290194 | 552475.7 | 7290197.4 | 1.7 | 3.4 |
| MN14-37 | 552454 | 7290392 | 552456 | 7290394.7 | 2.0 | 2.7 |
| MN14-13 | 552398 | 7290384 | 552402.5 | 7290387.9 | 4.5 | 3.9 |
| Mangazeisky South | | | | | | |
| MS14-02 | 552656 | 7289761 | 552655.6 | 7289767 | -0.4 | 5.7 |
| MS14-03 | 552638 | 7289785 | 552639.2 | 7289789 | 1.2 | 3.9 |
| MS14-04 | 552633 | 7289804 | 552632 | 7289807 | -1 | 3.2 |
| MS14-05 | 552621 | 7289828 | 552621.1 | 7289831 | 0.1 | 2.8 |
| MS14-07 | 552598 | 7289877 | 552597.9 | 7289879 | -0.1 | 1.8 |
| MS14-09 | 552608 | 7289915 | 552608.9 | 7289918 | 0.9 | 2.7 |
| MS14-10 | 552609 | 7289910 | 552609.3 | 7289914 | 0.3 | 4.2 |
| MS14-15 | 552684 | 7289777 | 552683.4 | 7289782 | -0.6 | 4.9 |
| MS14-16 | 552606 | 7289792 | 552605.4 | 7289796 | -0.6 | 4.2 |
| MS14-17 | 552581 | 7289839 | 552581.9 | 7289840 | 0.9 | 1.1 |
| Vertikalny Central | | | | | | |
| V08-080 | 551473 | 7283730 | 551471.3 | 7283730.9 | -1.7 | 0.9 |
| V09-145 | 551357 | 7283824 | 551356.4 | 7283822.5 | -0.6 | -1.5 |
| V13-48 | 551085 | 7284015 | 551085 | 7284016 | 0 | 1 |
| V13-48 | 551083 | 7284016 | 551085 | 7284016 | 2 | 0 |
| V14-05 | 551185 | 7283932 | 551186.7 | 7283930.6 | 1.7 | -1.4 |
| V14-06 | 551181 | 7283924 | 551180.4 | 7283923.6 | -0.6 | -0.4 |
| Sterzhnevoy | | | | | | |
| ST15-08 | 552940 | 7287072 | 552938 | 7287071 | -1.9 | -0.9 |
| ST15-04 | 552895 | 7287106 | 552894 | 7287106 | -1.4 | 0.4 |
| ST15-02 | 552913 | 7287167 | 552911 | 7287167 | -1.7 | 0 |
| ST15-05 | 552943 | 7287115 | 552940 | 7287115 | -2.7 | -0.4 |
| Vertikalny Northwest | | | | | | |
| V09-116 | 549129 | 7285542 | 549130.9 | 7285540.9 | 1.9 | -1.1 |
| VNW14-01 | 548980 | 7285572 | 548984.1 | 7285570.3 | 4.1 | -1.7 |
| VNW14-02 | 549019 | 7285563 | 549020.8 | 7285560.7 | 1.8 | -2.3 |
| VNW14-07 | 549145 | 7285525 | 549144 | 7285525.8 | -1 | 0.8 |
| VNW14-08 | 549171 | 7285515 | 549171.1 | 7285517 | 0.1 | 2 |
| VNW14-09 | 549159 | 7285504 | 549160.4 | 7285505.9 | 1.4 | 1.9 |
| VNW14-10 | 549171 | 7285487 | 549169.7 | 7285492.3 | -1.3 | 5.3 |
| VNW14-11 | 549155 | 7285433 | 549156.8 | 7285434.1 | 1.8 | 1.1 |
| VNW14-12 | 549176 | 7285421 | 549178.3 | 7285423.9 | 2.3 | 2.9 |

*table continues...*

| Drillhole/ Trench Name | Silver Bear | | Tetra Tech | | Δ X (m) | Δ Y (m) |
|---|---|---|---|---|---|---|
| | X (m) | Y (m) | X (m) | Y (m) | | |
| VNW14-13 | 549060 | 7285515 | 549062.2 | 7285514.5 | 2.2 | -0.5 |
| VNW14-14 | 549037 | 7285535 | 549040.8 | 7285532.9 | 3.8 | -2.1 |

Note: Δ – delta

### 12.1.3 INDEPENDENT CHECK SAMPLES

Independent samples of the drill core were not collected by Tetra Tech on the most recent site visit, due to restrictions in Russia on travelling with core samples. However, on previous site visits Tetra Tech collected one grab sample of massive galena from Trench K-1322 at Mangazeisky North and sent in to Actlabs in Ancaster, Ontario, for analysis. The assay report returned a value of 4,170 g/t silver. This sample is show below in (Figure 12.1).

**Figure 12.1 Grab Sample from Trench K-1322 at Mangazeisky North**

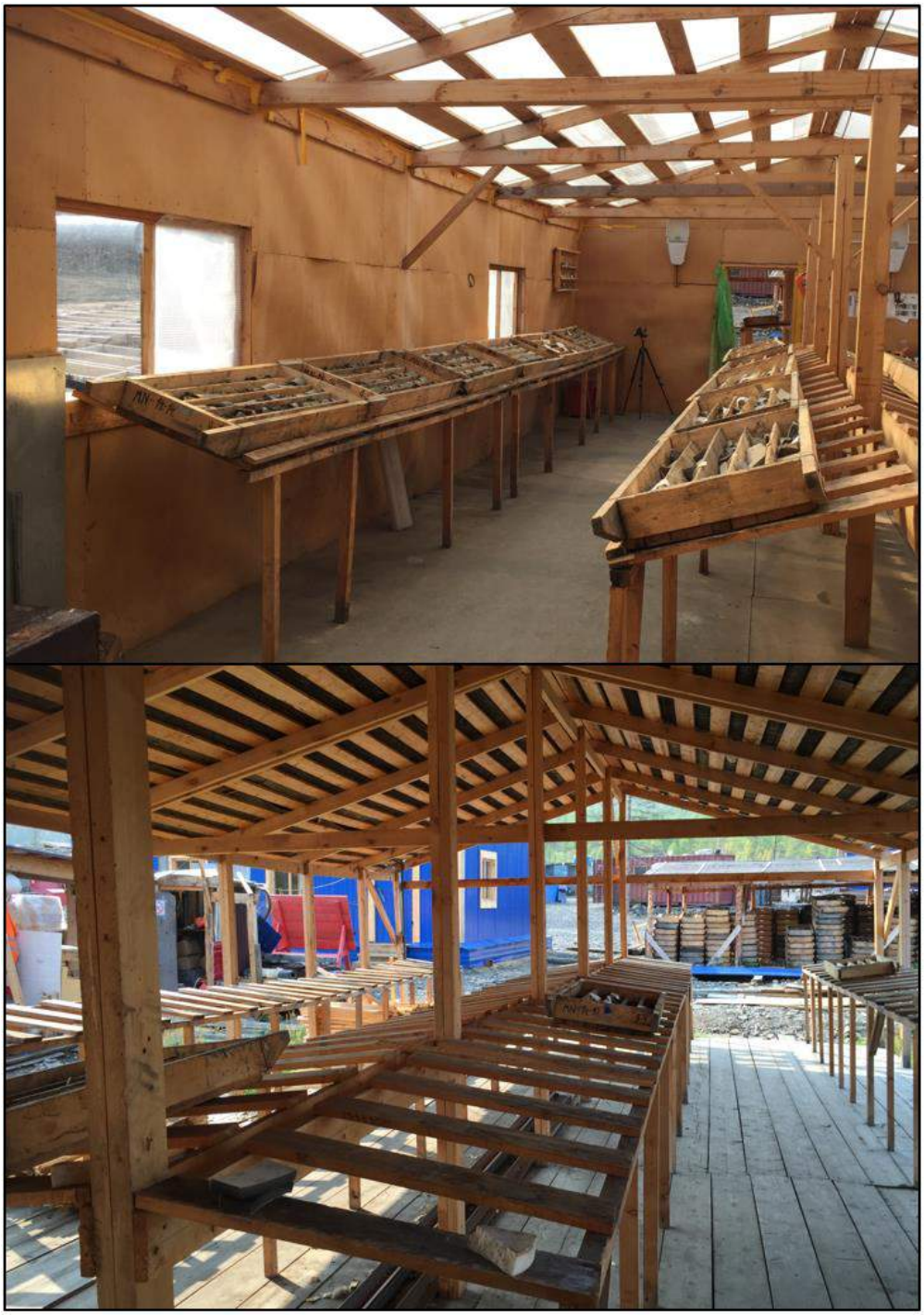
Source: Tetra Tech

### 12.1.4 CORE LOGGING AND SAMPLING

Upon receipt of all core boxes from any one drillhole, the core boxes were brought in and laid out on the core logging tables. Drill core was then aligned; geotechnical logging was carried out first, followed by geological core logging. Core logging was carried out or supervised by Mr. Kraushkin. Logging procedures are described in Section 10.0.

The logging facility was kept clean and tidy with sufficient lighting (Figure 12.2).

**Figure 12.2 Core Logging Facilities; Indoor and Outdoor**



Source: Tetra Tech

### *Core Samples*

Core splitting and sampling was carried out in batches as each drillholes or series of drillholes was completed. Sample intervals were selected based upon observations of lithology/mineralogy through mineralized intercepts, generally with three systematic samples taken before and after mineralization. Systematic samples were 1 m in length.

Sampling and QA/QC procedures were in place. Standards, duplicates and blanks were inserted at regular intervals. Drill core was split historically by pneumatic splitter and for recent campaigns by diamond saw, where one half was placed in the sample bag with the sample tag and the other half was returned to the core box for storage.

### *Core Sample Preparation Facilities*

The following equipment was inspected (Figure 12.3):

- pneumatic splitter
- two diamond saws
- two jaw crushers
- roller crusher
- sample dryer
- sample splitter.

No sample preparation activities were carried out during the site visit. Sample preparation and equipment was kept reasonably clean and tidy.

**Figure 12.3 Sample Preparation Equipment; (left to right) Pneumatic Splitter, Sample Dryer (Kiln), Samples Being Crushed and Jaw Crusher**

Source: Tetra Tech

### *Storage of Core and Sample Pulps*

All storage facilities at the camp were inspected. Drill core from previous drill programs are stored under covered shelters adjacent to the core logging and sample preparation facilities (Figure 12.4). The core boxes are stacked by drillhole.

**Figure 12.4 Core Storage Facilities; Current and New Core Storage Facilities**

Source: Tetra Tech

All sample pulps from the previous drill programmes are stored on site at the camp. All sample pulps are stacked on sturdy wooden shelves by drillhole number (Figure 12.5).

**Figure 12.5 Sample Pulps Storage**

Source: Tetra Tech

Tetra Tech observed outcrops in trenches at Mangazeisky North & South, Porfirovy, Vertikalny, Vostotchny, Kis kuel and Sterzhnevoy, most of which were obviously mineralised. Native silver and malachite were seen in hands specimen at Sterzhnevoy.

**Figure 12.6 Mineralised Veins in Outcrop at Verticalny Central (Left) and Mangazeisky North (Right)**

Source: Tetra Tech

## 12.2 TETRA TECH OPINION

It is Tetra Tech's opinion that the current drill program, logging and sampling procedures are consistent with recognised industry best practices and are considered adequate for this type of deposit.

## 12.3 OFFICE BASED DATA VERIFICATION

### 12.3.1 ASSAY CERTIFICATES

Silver Bear provided Tetra Tech with signed portable document format (.pdf) assay certificates for the drilling campaigns. Tetra Tech checked 10% of the assay certificates against the values contained within the database. No errors were encountered.

# 13.0 MINERAL PROCESSING AND METALLURGICAL TESTING

## 13.1 SUMMARY

This section details the mineralogical and metallurgical test work completed to date on the Mangazeisky ore samples.

Historical investigations were conducted by two organisations: TSNIGRI (2008) and the National Institute of Non-ferrous Metals (GINTSVETMET) (2011). A high-level summary of these investigations is presented in this section.

As part of the feasibility study, additional mineralogical and metallurgical test work was completed by two commercial laboratories: SGS Vostok (Chita, Russia) (2014) and TOMS (Irkutsk, Russia) (2015a; 2015b).

SGS Vostok tested a composite sample, which comprised samples collected from dedicated metallurgical drillholes within the Central Zone of the orebody, representing the oxide ore. The SGS Vostok test work was completed between January 2014 and December 2014.

TOMS completed two separate test work programs in 2015. TOMS initially completed a leach variability test program in February 2015, followed by leach optimisation and comminution test work for a primary ore composite. The primary ore testing was completed between November 2015 and December 2015.

Tetra Tech analysed all the metallurgical test work results with the objective of identifying the optimal process flowsheet. The metallurgical studies indicate that the oxide ore is amenable to gravity concentration and cyanidation and can be efficiently processed using a gravity and agitated tank leach based flowsheet. The study also indicates that the primary ore is amenable to cyanidation and can be effectively processed by a whole ore leach method.

Based on the metallurgical test work results, the LOM recovery for silver is estimated to be 85% for oxide ore and 69.6% for primary ore.

## 13.2 HISTORICAL TEST WORK REVIEW

### 13.2.1 TSNIGRI TEST WORK RESULTS (2008)

*BACKGROUND*

Two samples collected from trenches were used for the 2008 test work programme, which consisted of:

- elemental analysis
- phase analysis
- mineralogical characterisation
- chemical analysis of crushed mineral by size
- gravity concentration of the feed mineral
- flotation of gravity tailings
- cyanidation of flotation tailings.

### *Sample Mineralogy*

This section summarizes the main conclusions of TSNIGRI (20089).

Two trench samples were tested; the key minerals found are detailed in Table 13.1.

**Table 13.1 2008 Sample Chemical Analysis**

| Sample No. | Ag (g/t) | Pb (%) | Zn (%) | Cu (%) |
|---|---|---|---|---|
| Sample 1 | 340 | 1.63 | 1.14 | - |
| Sample 2 | 575 | 6.74 | 2.35 | 0.16 |

Both samples were analysed for minerals associated with silver (Table 13.2). It is evident that the silver association varies significantly between the two samples; however, for both samples the majority of silver is found within the mineral grain boundaries.

**Table 13.2 Silver Association**

| Silver Characteristics | Sample 1 | | Sample 2 | |
|---|---|---|---|---|
| | Ag (g/t) | Distribution (%) | Ag (g/t) | Distribution (%) |
| Free with Clear Surface | - | - | - | - |
| Covered with Film and Enclosed in Acid-soluble Minerals | 112.3 | 17.55 | 0.1 | 0.01 |
| In Joints | 487.0 | 76.09 | 273.0 | 48.75 |
| Enclosed in Galena | 26.2 | 4.09 | 156.7 | 27.98 |
| Enclosed in Sphalerite | 7.2 | 1.13 | 82.2 | 14.68 |
| Enclosed in Copper Minerals and Pyrite | 7.3 | 1.14 | 48.0 | 8.57 |
| In Acid-insoluble Residue | - | - | - | - |
| **Total** | **640.0** | **100.00** | **560.0** | **100.00** |

In Sample 1, the majority of silver was present in open joints, with the balance present as free silver with film coatings. There was a poor association with sulphides. However, with Sample 2, there were no coated silver or acid-soluble minerals, and approximately half of the silver content occurred in open joints. The remainder of the silver was associated with sulphide minerals, mainly galena, but also sphalerite, with some pyrite and copper minerals. This highlights the variability in the samples taken.

### GRAVITY CONCENTRATION

The focus of the test work programme was to maximise recovery of all metals into saleable gravity and flotation concentrates. Gravity separation was attempted first through a two-stage gravity table concentration, and second via a single table, followed by Knelson concentration of the tailings. The concentrates from the two gravity processes were combined to predict a total silver product grade and recovery.

On tabling, Sample 1 produced silver recoveries of 26.76% and Knelson concentration of the table tails achieved 24.32% silver recovery. The silver concentrate grades achieved were over 9,000 g/t for both products.

Sample 2 achieved better results, with the first test achieving a silver recovery of 45.40% and the second 49.99%. However, the silver grades were lower at approximately 2,500 g/t for both products.

The gravity test work indicated the highly-variable nature of the samples tested and suggested that additional upgrading of both the gravity concentrate and tailings is necessary to achieve an acceptable silver concentrate grade and recovery.

### FLOTATION

Flotation recovery was evaluated on the first-stage gravity tailings for both Sample 1 and Sample 2. Flotation was undertaken at a number of grind sizes, which indicated a particle size ($P_{85}$) of 71 µm was optimum for Sample 1, and a particle size ($P_{80}$) of 71 µm was optimum for Sample 2. This once again indicates the difference between the two samples. Additional flotation tests were carried out to optimise metal recovery at varied reagent additions. The optimum results achieved are highlighted in Table 13.3.

**Table 13.3 Gravity and Flotation Test Work Overview**

| Products | Mass (%) | Metal Content | | | Recovery | | |
|---|---|---|---|---|---|---|---|
| | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| **Sample No. 1** | | | | | | | |
| Gravity Concentrate of Stages I and II | 1.68 | 9,265.67 | 59.89 | 2.07 | 24.32 | 60.64 | 2.81 |
| Gravity Tails | 98.32 | 491.26 | 0.66 | 1.22 | 75.68 | 39.36 | 97.19 |
| Feed | 100.00 | 638.23 | 1.65 | 1.24 | 100.00 | 100.00 | 100.00 |
| ***Flotation of Gravity Tails*** | | | | | | | |
| Flotation Concentrate | 3.42 | 12,320.00 | 6.55 | 17.57 | 66.02 | 13.54 | 47.45 |
| Flotation Tailings | 94.90 | 65.00 | 0.45 | 0.70 | 9.66 | 25.82 | 49.74 |
| Total Product Recovery | - | - | - | - | 90.34 | 74.18 | 50.26 |
| **Sample No. 2** | | | | | | | |
| Gravity Concentrate of Stages I and II | 11.42 | 2,517.90 | 44.68 | 4.79 | 49.99 | 77.28 | 20.79 |
| Gravity Tails | 88.58 | 324.75 | 1.69 | 2.36 | 50.01 | 22.71 | 79.21 |
| Feed | 100.00 | 575.30 | 6.60 | 2.63 | 100.00 | 100.00 | 100.00 |

*table continues...*

| Products | Mass (%) | Metal Content | | | Recovery | | |
|---|---|---|---|---|---|---|---|
| | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| ***Flotation of Gravity Tails*** | | | | | | | |
| Flotation Concentrate | 5.31 | 4,680.00 | 15.20 | 20.00 | 43.23 | 12.23 | 40.35 |
| Flotation Tailings | 83.27 | 46.80 | 0.83 | 1.23 | 6.78 | 10.48 | 38.86 |
| **Total Product Recovery** | - | - | - | - | **93.22** | **89.51** | **61.14** |

Note: *The tailings grade was adjusted by Tetra Tech to ensure correct silver balance.

#### *CYANIDATION*

Flotation tailings were leached with cyanide to assess if this would increase silver recovery. A silver recovery of 55 to 71% was achieved, representing an additional overall recovery increase of 5 to 6%. The test work conditions were undertaken at high-cyanide consumptions; however, lower cyanide dosages were not trialled during these tests, and therefore the optimum cyanide addition was not determined.

### 13.2.2 GINTSVETMET TEST WORK RESULTS (2011)

#### *BACKGROUND*

The test work carried out by GINTSVETMET (2011) investigated the following aspects of the ore:

- Chemical composition of a composite sample and the drillhole samples were analysed.
- Two composite samples were made up from two drill zones labelled SB-1 and SB-2. These two samples were analysed for chemical composition and mineralogy. Elemental analysis and the association of the silver were determined for sample SB-2:
  - SB-1 comprised of material collected from surface and oxidised material
  - SB-2 was a composite sample made up from drill core samples (the laboratory report states that this sample is the most representative of the mineral deposit).

Samples were used for beneficiation test work, which included:

- milling parameters on SB-2
- laboratory flotation tests on sample SB-1
- gravity concentration on feed mineral
- gravity concentration on flotation tailings
- separate flotation of fine and coarse material
- locked flotation test work
- cyanidation of ROM mineral and flotation concentrate.

### SAMPLE MINERALOGY

The chemical composition of the samples is summarised in Table 13.4.

**Table 13.4 Sample Chemical Composition**

| Element | Unit | SB-1 | SB-2 |
|---|---|---|---|
| Silver | g/t | 695 | 710 |
| Lead | % | 1.3 | 4.8 |
| Zinc | % | 1.3 | 1.7 |
| Copper | % | 0.1 | 0.1 |
| Iron | % | 10.9 | 18.9 |
| Antimony | % | 0.1 | 0.1 |
| Arsenic | % | 0.6 | 0.3 |
| Sulphur | % | 1.5 | 3.6 |
| Calcium Oxide | % | 0.3 | 0.5 |
| Sodium Oxide | % | 0.2 | 0.1 |
| Magnesium Oxide | % | 0.6 | 1.2 |
| Silicon Oxide | % | 52.6 | 34.0 |
| Aluminium Oxide | % | 17.2 | 11.2 |

SB-2 is understood to be the most representative of the mineral deposit, and was analysed for silver mineral association. Table 13.5 indicates that the majority of the silver is free (47.4%), with the remainder associated with galena, sphalerite, other sulphides, oxides/sulphosalts or rocks, and carbonates. It is anticipated that the silver recovery on cyanidation of these minerals will be 98% free/open; 80% lead sulphides; 80% zinc and iron sulphides; 90% other sulphides, oxides, and sulphosalts; and 85% rocks and carbonates. Based on these estimations, the cyanide recovery will be approximately 91%; however, this requires confirmation via test work.

**Table 13.5 SB-2 Silver Association**

| Silver Form | Grade (g/t) | Distribution (%) |
|---|---|---|
| Free/Open | 336.2 | 47.4 |
| ***Associations with:*** | | |
| Galena | 115.9 | 16.3 |
| Sphalerite | 78.5 | 11.1 |
| Other Sulphides, Oxides and Sulphosalts | 131.6 | 18.6 |
| Rock and Carbonates | 46.7 | 6.6 |
| **Total** | **708.9** | **100.0** |

### MILLING PARAMETERS

The key milling parameters outlined in GINTSVETMET (2011) include:

- Protodyakonov hardness: 11 to 23
- Bond Work Index: 12 to 13 kWh/t.

### *Flotation Test Work*

Stage flotation of lead and zinc was undertaken at various grind sizes. The optimum grind size was found to be 96.5% -71 µm. The results are summarised in Table 13.6.

**Table 13.6 SB-1 Flotation Test Work Results at 96.5% -71 µm**

| Products | Mass (%) | Metal Content | | | Recovery | | |
|---|---|---|---|---|---|---|---|
| | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| Lead Concentrate – Intermediate | 2.55 | 2,750.00 | 4.83 | 1.10 | 10.17 | 7.93 | 3.01 |
| Lead Concentrate – Main | 2.32 | 1,700.00 | 2.08 | 1.10 | 5.72 | 3.11 | 2.74 |
| Lead Concentrate – Oxidised | 4.88 | 1,400.00 | 2.43 | 2.05 | 9.90 | 7.63 | 10.75 |
| Zinc Product | 1.95 | 1,350.00 | 2.29 | 1.80 | 3.82 | 2.88 | 3.77 |
| Tailings | 88.30 | 550.00 | 1.38 | 0.84 | 70.40 | 78.45 | 79.72 |
| Feed | 100.00 | 689.86 | 1.55 | 0.93 | 100.00 | 100.00 | 100.00 |

Note: *The tailings grade was adjusted by Tetra Tech to ensure correct silver balance.

### *Gravity Concentration*

Gravity concentration was trialled on the raw mineral sample SB-1 at a number of grind sizes, as well as flotation tails. Gravity concentration was attempted on the feed mineral at 55.7%, 79.1%, and 96.5% -71 µm. A maximum silver recovery of 17.63% was achieved at a grind size of 79.1% -71 µm. This indicates additional processing is required to recover silver from the gravity tailings.

Gravity concentration of flotation tailings showed 5.26% silver recovery to gravity concentrate. This indicates poor upgrade of flotation tailings by gravity.

### *Locked Cycle Flotation Test Work*

Sodium carbonate, butyl xanthate, sodium sulphide, and frother reagents were used as flotation reagents in the locked cycle test work. Sample SB-1 showed poor silver, zinc, and lead recoveries to the lead concentrate, as outlined in Table 13.7.

**Table 13.7 SB-2 Locked Cycle Flotation Test Results**

| Products | Mass (%) | Metal Content | | | Recovery | | |
|---|---|---|---|---|---|---|---|
| | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| Lead Concentrate | 1.59 | 8,320 | 18.80 | 1.00 | 18.56 | 19.93 | 1.57 |
| Tailings | 98.41 | 590 | 1.22 | 1.01 | 81.44 | 80.07 | 98.43 |
| Feed | 100.00 | 713 | 1.50 | 1.01 | 100.00 | 100.0 | 100.00 |

Note: The tailings grade was adjusted by Tetra Tech to ensure the correct silver balance.

Sample SB-2 was therefore the focus of the locked cycle flotation test work. Zinc sulphate, dimethyl dithiocarbamate, and frother were used to recover a lead concentrate, whilst lime, copper sulphate, butyl xanthate, and frother agent were used for zinc recovery. The results from the locked cycle tests are shown in Table 13.8.

**Table 13.8 SB-2 Locked Cycle Flotation Test Results**

| Products | Mass (%) | Metal Content Ag (g/t) | Metal Content Pb (%) | Metal Content Zn (%) | Recovery Ag (%) | Recovery Pb (%) | Recovery Zn (%) |
|---|---|---|---|---|---|---|---|
| Lead Concentrate (Rougher) | 4.15 | 5,500.00 | 58.00 | 4.84 | 33.06 | 47.90 | 10.75 |
| Lead Gravity Concentrate | 2.39 | 7,400.00 | 52.00 | 5.58 | 25.62 | 24.73 | 7.14 |
| Lead Flotation Concentrate | 1.24 | 9,525.00 | 55.30 | 7.65 | 17.11 | 13.65 | 5.08 |
| Total Lead Concentrate | 7.78 | 6,725.19 | 55.73 | 5.52 | 75.79 | 86.28 | 22.96 |
| Zinc Concentrate | 2.21 | 2,550.00 | 8.30 | 42.10 | 8.16 | 3.65 | 49.79 |
| Zinc Flotation Tailings | 3.03 | 570.00 | 1.20 | 1.30 | 2.50 | 0.72 | 2.11 |
| Tailings | 86.98 | 107.50 | 0.54 | 0.54 | 13.54 | 9.35 | 25.14 |
| Feed | 100.00 | 690.35 | 5.03 | 1.87 | 100.00 | 100.00 | 100.00 |

Note: *The tailings grade was adjusted by Tetra Tech to ensure the correct silver balance.

The zinc grade of the zinc concentrate appears to be low when compared with typical smelter concentrate requirements.

#### *Cyanidation Test Work*

Cyanidation was carried out at 44 µm on feed mineral and flotation concentrate, in order to assess the amenability of the mineral to cyanidation. Silver recovery during leaching of the feed mineral ranged from 19.3 to 51.3%. Flotation concentrate cyanidation achieved silver recoveries from 55.2 to 90.8%.

The wide range of recoveries achieved shows the variability in the samples used for the test work. The key to ensuring accurate predictor test work is the collection of representative samples on which to carry out the work. Tetra Tech is not aware of the sample selection method, or from which mineralised zone the samples originate, therefore, an accurate assessment of the mineral's amenability to cyanidation is not possible. Subsequent test work was aimed at addressing this and assessed the potential for cyanidation leaching of the mineral deposit.

### 13.2.3 Conclusions of Historical Work

Silver is by far the most significant economic component within the ore and as a result, the recovery of the silver is the focus of this study. The Project's processing plant is in an isolated environment where access conditions are difficult, and the production of a concentrate product would be impractical in terms of transport requirements and supply and availability of flotation reagents. As a result, Tetra Tech proposes that a simple process flowsheet that produces a final silver product would be the most practical solution for this ore.

The test work carried out during the historical studies indicates that highly variable samples were taken and tested for gravity, flotation, and cyanide recovery. The test work did not simulate the processing scheme that Tetra Tech proposes. It was not possible to effectively evaluate the performance of a Knelson gravity concentrator followed by intensive leaching of the gravity concentrate and standard cyanide leaching of the gravity tails. As the test work did not provide adequate predictions of actual process performance, the mineralogy of feed sample SB-2 was used to determine the expected gravity and cyanidation recovery achievable from this

mineral. This was based on the fact that the SB-2 was stated as being most representative of the actual mineralisation in the GINTSVETMET (2011) test work report.

If Silver Bear were to implement a gravity and flotation process scheme, a number of site-specific problems would arise. The flotation test work indicates that the zinc concentrate produced did not achieve a saleable zinc grade. Additionally, owing to the isolated plant location and difficult transport logistics, gravity and lead concentrate would require leaching to recover the silver prior to shipment off site, thereby reducing the value of the lead concentrate. Tetra Tech, therefore, proposes a less complex process design that will make certain that all of the ROM feed is leached, ensuring maximum opportunity for silver recovery.

## 13.3 FEASIBILITY STUDY TEST WORK (SGS VOSTOK 2014)

### 13.3.1 METALLURGICAL SAMPLING

#### *SAMPLE BACKGROUND*

Tetra Tech was not involved with the sample selection for the metallurgical test work completed at SGS Vostok, but did review the sample lists provided by Silver Bear and SGS Vostok. It is understood that the test work samples were collected from nine metallurgical drillholes (Figure 13.1) within the Central Zone (Figure 13.2) of the mineralised areas. It appears that the drillholes covered the high-grade areas of the Central Zone, which could be mined during the early years of operation.

**Figure 13.1 Location of Metallurgical Drillholes**

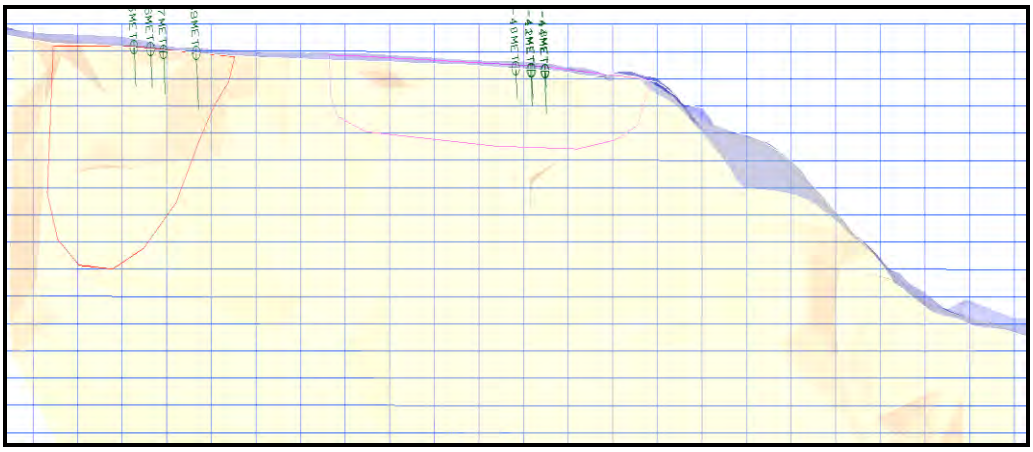
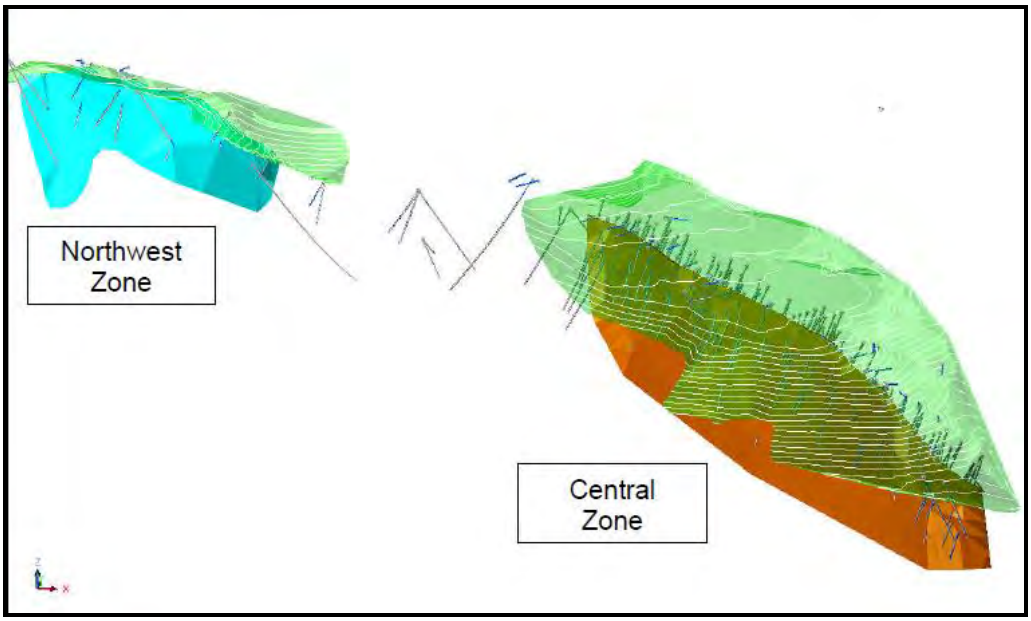


**Figure 13.2 Mineralised Zones within the Orebody**




Metallurgical samples were shipped to SGS Vostok in nine boxes as shown in Table 13.9

**Table 13.9 Samples Sent to SGS Vostok**

| Pit Location | Hole ID | Test Work Stage |
|---|---|---|
| Zone 1 | V13-35 | Stage 1 |
| | V13-36 | |
| | V13-37 | |
| | V13-38 | |
| | V13-39 | |
| Zone 2 | V13-40 | Stage 2 |
| | V13-41 | |
| | V13-42 | |
| | V13-43 | |

### *Sampling Program*

Tetra Tech was not directly involved with the selection or QA/QC aspects of the sampling programme. However, it is understood that trained personnel were involved in all stages of the sampling and adhered to industry best practices of sampling. Satisfactory evidence to support this was shown to Tetra Tech during a site visit to the SGS Vostok laboratories in July 2014.

A list of the samples used in the metallurgical test work programs is shown in Table 13.9.

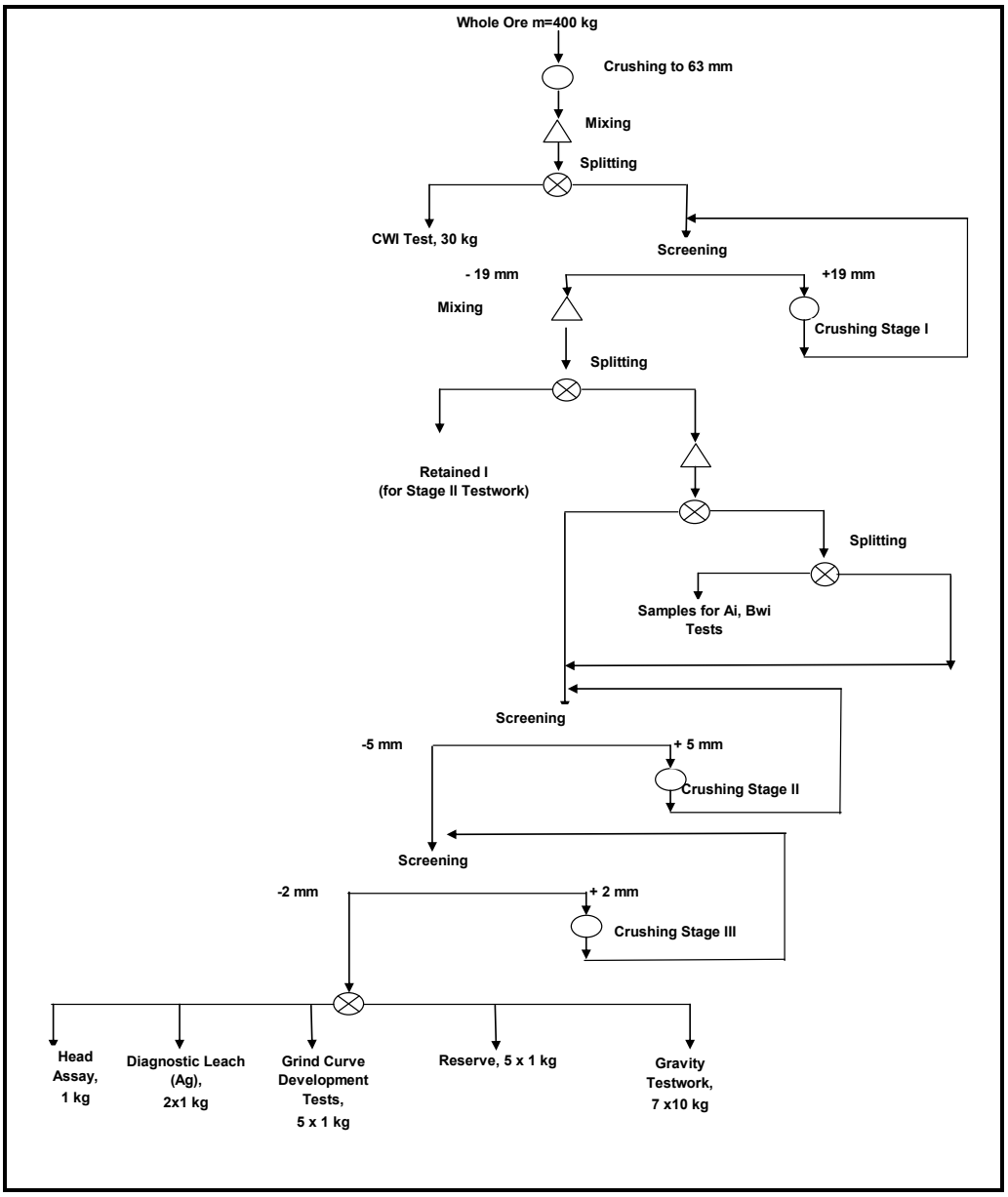
### *Sample Preparation*

The samples were delivered to SGS Vostok in two wooden crates (Figure 13.3) as whole HQ core (Figure 13.4). SGS Vostok blended samples belonging to Zone 1 together in order to make a homogenised composite. Samples were then taken for various tests as shown in Figure 13.5.

**Figure 13.3 Sample Delivered to SGS Vostok**

**Figure 13.4 One of the Delivered Core Boxes at SGS Vostok**

**Figure 13.5 Sample Preparation Flowsheet**




### *ORE CHARACTERISTICS*

Vertikalny ore is characterized as a polymetallic silver-lead-zinc, partially oxidized deposit. Silver is the most significant economic metal, with the presence of lead and zinc at less significant quantities.

Most of the silver is present in open joints with other minerals (metallic silver and acanthite), with the balance as free silver with film coatings. There is a very low association of silver with sulphides is observed in the sample tested by SGS Vostok.

The most abundant silver mineral is acanthine with the presence of galena and sphalerite, with subordinate values of other sulphides.

### *Physical Properties*

The specific gravity of the samples was determined in the SGS Vostok laboratory. A summary of the specific gravity results is shown in Table 13.10. No other physical properties of the ore were determined during the current test work program.

**Table 13.10 Specific Gravity of the Ore**

| Description | Specific Gravity (g/cm³) | |
|---|---|---|
| | Sample 1 | Sample 2 |
| Maximum Value | 2.66 | 3.01 |
| Minimum Value | 2.28 | 2.34 |
| Mean | 2.50 | 2.65 |
| Standard Deviation | 0.10 | 0.12 |

### *Chemical Analysis*

SGS Vostok analysed the head sample for silver, gold, copper, lead, and zinc assays, and conducted a whole rock analysis for all other major elements. A summary of the assay and whole rock analyses are shown in Table 13.11 and Table 13.12.

**Table 13.11 Summary of Head Assays**

| Element | Unit | Assay |
|---|---|---|
| Silver | g/t | 1,112.50 |
| Gold | g/t | 0.07 |
| Copper | % | 0.14 |
| Lead | % | 1.99 |
| Zinc | % | 1.80 |

Note: *Silver assays ranged from 1,020 g/t to 1,150 g/t with an average of 1,112.5 g/t.

**Table 13.12 Summary of Whole Rock Analysis**

| Element | Unit | Assay | Element | Unit | Assay |
|---|---|---|---|---|---|
| Carbon (Organic) | % | 0.06 | Cadmium | ppm | 130 |
| Sulphur (Sulphides) | % | 0.3 | Chromium | ppm | 30 |
| Carbon (Total) | % | 0.98 | Iron | % | 34.2 |
| Sulphur (Total) | % | 1.52 | Potassium | % | 1.01 |
| Sulphur (elemental) | % | 0.28 | Magnesium | % | 0.67 |
| Beryllium | ppm | <0.5 | Manganese | ppm | 40,100 |
| Bismuth | ppm | <5 | Nickel | % | <0.001 |
| Cobalt | ppm | 7 | Phosphorus | % | 0.03 |
| Mercury | ppm | <1 | Antimony | % | 0.119 |
| Lanthanum | ppm | 0.9 | Scandium | ppm | <5 |
| Lithium | ppm | <1 | Tin | ppm | 350 |
| Molybdenum | ppm | 2 | Strontium | ppm | 30 |
| Sodium | % | 0.01 | Titanium | % | 0.12 |
| Aluminium | % | 2 | Vanadium | ppm | 20 |
| Arsenic | % | 0.194 | Tungsten | ppm | <50 |
| Barium | ppm | 90 | Yttrium | ppm | 12 |
| Calcium | % | 0.2 | Silicon Dioxide | % | 19.7 |

### 13.3.2 MINERALOGICAL TEST WORK

SGS Lakefield in Canada completed a mineralogical characterisation and silver deportment study on the Mangazeisky sample prepared and sent by SGS Vostok. The mineralogical investigation and the key results are summarised in this section. Further details can be found in Appendix A.

The mineralogical characterization of the sample was carried out with heavy liquid separation (HLS) followed by QEMSCAN® and chemical analysis.

The purpose of the mineralogical characterization was to determine the overall mineral assemblage and the liberation and association of the silver minerals.

#### *SAMPLE PREPARATION*

The sample was stage-crushed to 150 µm. Sub-samples were riffled for assays by ICP, whole rock analysis, lead, zinc, sulphur, silver, and for mineralogical analysis. The remainder of the sample was screened at 25 µm to generate a +25 µm and a -25 µm fraction. Both fractions were subjected to HLS at 3.1 specific gravity. The sink products were submitted for whole rock analysis by ICP, zinc, lead, and barium by x-ray fluorescence (XRF), sulphur by Leco, and silver by fire assay. A micro-riffled sub-sample from the +25 µm float fraction was submitted for silver analysis.

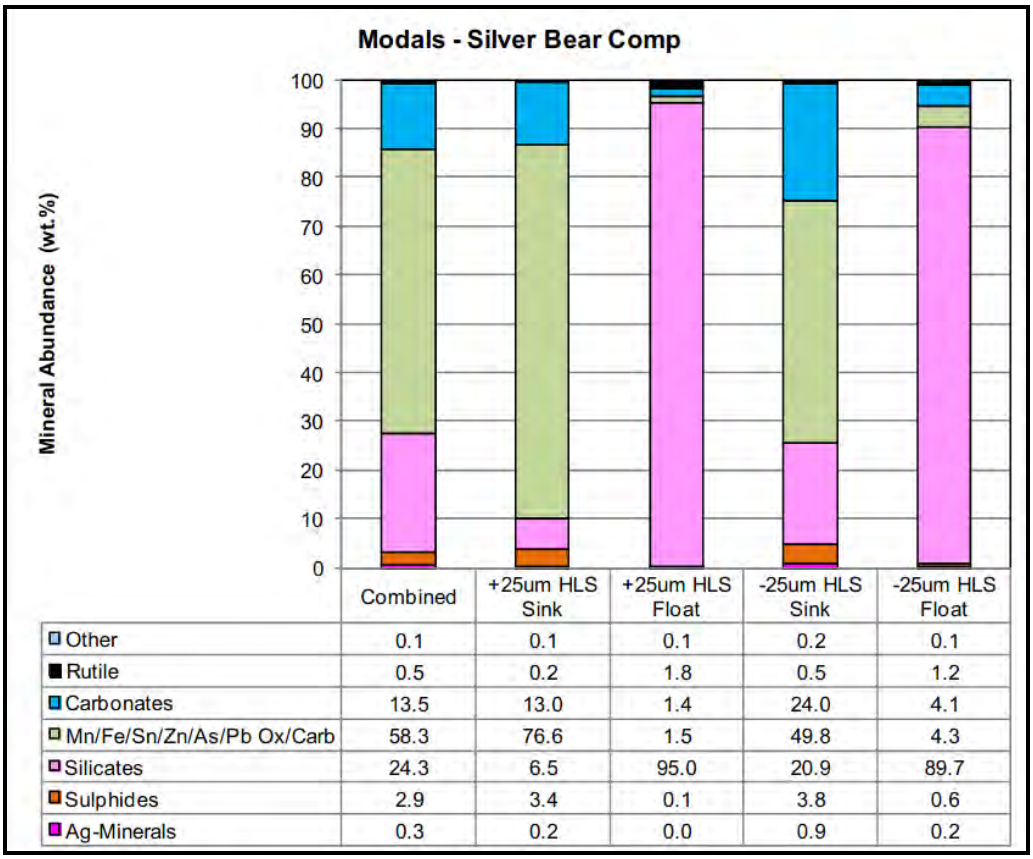
#### *Modal Mineralogy*

The mineralogical characterization indicated that the sample consists mainly of manganese-iron oxides/carbonates (mainly goethite and hematite and account for 58% total), followed by quartz (15%), siderite (14%), and muscovite (6%), and traces of K-feldspar, biotite, chlorite, clays, amphibole, zinc/manganese oxide, rutile, and other minerals.

It was also indicated that the silver minerals include silver-chlorides, silver sulphide, silver-rich tetrahedrite, and silver-lead-sulfosalts. The other sulphides included trace amounts of pyrite, chalcopyrite, stannite, covellite/chalcocite, sphalerite, galena and arsenopyrite.

A summary of the modal mineralogy is shown in Figure 13.6.

**Figure 13.6 Summary of Modal Mineralogy**




| | Combined | +25um HLS Sink | +25um HLS Float | -25um HLS Sink | -25um HLS Float |
|---|---|---|---|---|---|
| Other | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 |
| Rutile | 0.5 | 0.2 | 1.8 | 0.5 | 1.2 |
| Carbonates | 13.5 | 13.0 | 1.4 | 24.0 | 4.1 |
| Mn/Fe/Sn/Zn/As/Pb Ox/Carb | 58.3 | 76.6 | 1.5 | 49.8 | 4.3 |
| Silicates | 24.3 | 6.5 | 95.0 | 20.9 | 89.7 |
| Sulphides | 2.9 | 3.4 | 0.1 | 3.8 | 0.6 |
| Ag-Minerals | 0.3 | 0.2 | 0.0 | 0.9 | 0.2 |

The x-ray diffraction (XRD) analysis indicated that the sample consists mainly of quartz, goethite, hematite, and mica, minor galena, K-feldspar, siderite, montmorillonite, illite, hausmannite, ferrihydrite, and akaganeite, and traces of sphalerite, ramsdellite, bixbyite, and magnetite.

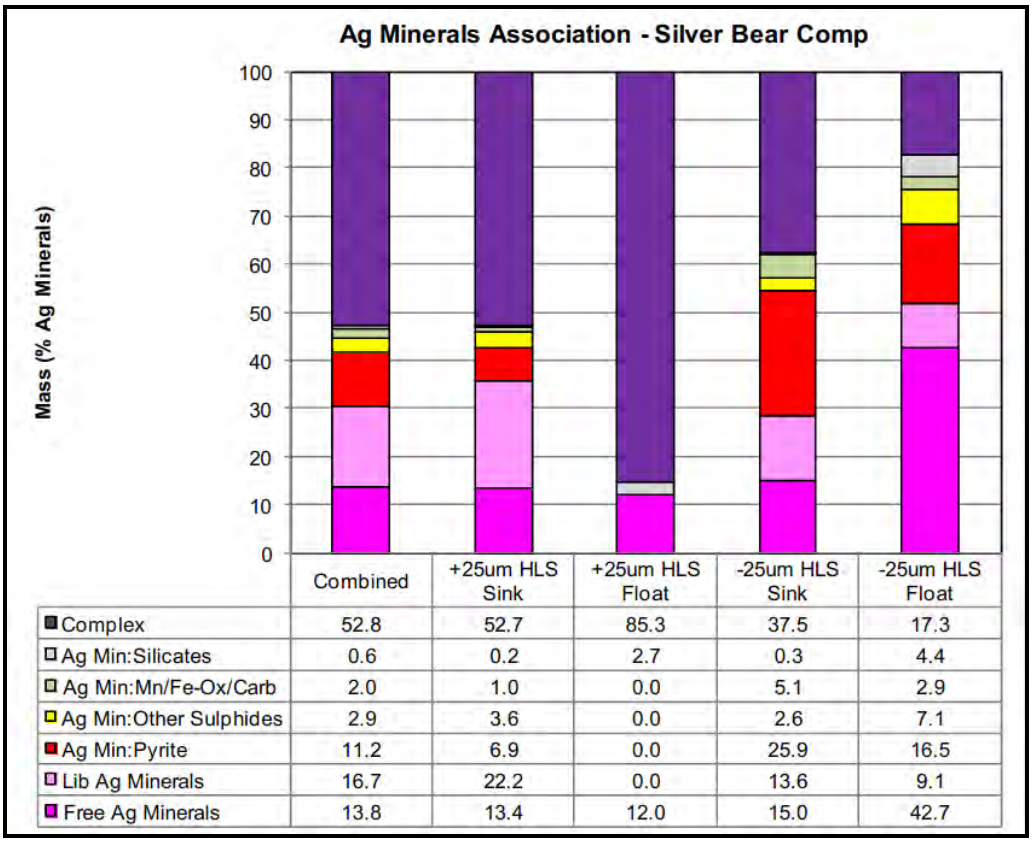
### *Liberation, Association and Exposure of Silver Minerals*

The liberation and association of silver minerals is shown in Figure 13.7, which illustrates that they are poorly liberated (at approximately 31%). A significant amount occurs as complex particles (53% as ternary and quaternary middlings), associations with pyrite (11%), various sulphides (3%), and carbonates/oxides and sulfosalts (2%).

Liberation is poor in both the +25 µm sink and float fractions at 36% and 12%, respectively. Liberation is 29% and 52% in the -25 µm sink and float, respectively. Note that the -25 µm float fraction accounts for only 0.3% of the total mass of the sample. Therefore, its contribution to the overall liberation is negligible.

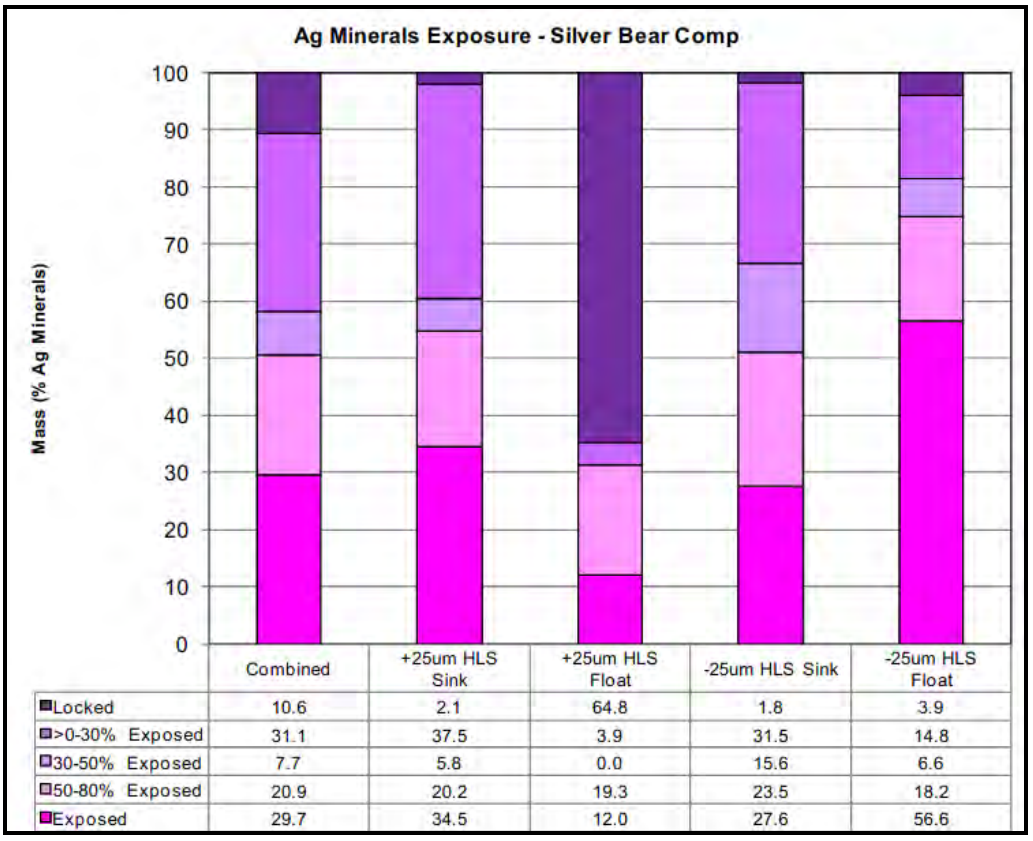
The exposure of silver minerals is shown in Figure 13.8. For the overall sample, the silver minerals that are well exposed (greater than 30% exposure surface) account for 59%, moderately exposed (greater than 0 – less than 30%) for 31%, and locked for 11%. The exposure of silver minerals is similar in the +25 µm sink fraction (61% well exposed, 37% moderately exposed and 2% locked), and -25 µm sink fraction (66%, 32% and 2%, respectively). However, 65% of the silver minerals are not exposed in the -25 µm float fraction.

**Figure 13.7 Liberation and Association of Silver Minerals**




| | Combined | +25um HLS Sink | +25um HLS Float | -25um HLS Sink | -25um HLS Float |
|---|---|---|---|---|---|
| Complex | 52.8 | 52.7 | 85.3 | 37.5 | 17.3 |
| Ag Min:Silicates | 0.6 | 0.2 | 2.7 | 0.3 | 4.4 |
| Ag Min:Mn/Fe-Ox/Carb | 2.0 | 1.0 | 0.0 | 5.1 | 2.9 |
| Ag Min:Other Sulphides | 2.9 | 3.6 | 0.0 | 2.6 | 7.1 |
| Ag Min:Pyrite | 11.2 | 6.9 | 0.0 | 25.9 | 16.5 |
| Lib Ag Minerals | 16.7 | 22.2 | 0.0 | 13.6 | 9.1 |
| Free Ag Minerals | 13.8 | 13.4 | 12.0 | 15.0 | 42.7 |

**Figure 13.8 Exposure of Silver Minerals**




| | Combined | +25um HLS Sink | +25um HLS Float | -25um HLS Sink | -25um HLS Float |
|---|---|---|---|---|---|
| Locked | 10.6 | 2.1 | 64.8 | 1.8 | 3.9 |
| >0-30% Exposed | 31.1 | 37.5 | 3.9 | 31.5 | 14.8 |
| 30-50% Exposed | 7.7 | 5.8 | 0.0 | 15.6 | 6.6 |
| 50-80% Exposed | 20.9 | 20.2 | 19.3 | 23.5 | 18.2 |
| Exposed | 29.7 | 34.5 | 12.0 | 27.6 | 56.6 |

Based on the mineralogical characterization the following primary conclusions can be drawn.

- The SGS Vostok sample consisted mainly of manganese-iron oxides/carbonates (58%), followed by quartz (15%), siderite (14%), and muscovite (6%), and traces of K-feldspar, biotite, chlorite, clays, amphibole, zinc/manganese-oxide, rutile, and other minerals.
- Silver minerals included chlorargyrite, silver sulphide and silver-antimony-lead sulfosalts, silver-rich tetrahedrite, and silver-lead sulfosalts.
- Silver minerals are poorly liberated (approximately 31%), and mainly occur as various middling particles and complex particles with the gangue minerals in the sample. Liberation is poor in both the +25 µm sink and float fractions at 36% and 12%, respectively, and 29% in the -25 µm sink fraction.
- Silver minerals with well exposed surface area (greater than 30% exposure) account for 59%, moderately exposed (greater than 0 – less than 30%) for 31% and locked for 11%. Therefore, chemical recovery of silver at 100% passing 150 µm grind would likely yield better grades and recoveries.

#### *Diagnostic Leach Tests*

Silver diagnostic leach tests were conducted on a representative sample at a grind of $P_{80}$ = 75 µm according to two different standard procedures. The summary of the results are shown in Table 13.13. Details of the test procedures can be seen in Appendix A.

**Table 13.13 Summary of Diagnostic Leach Results**

| Silver Deportment | Distribution (%) | |
|---|---|---|
| | Method 1 | Method 2 |
| Free Silver | 0.10 | 0.10 |
| Open Intergrowths | 89.60 | 89.70 |
| Amenable to Cyanidation | 89.70 | 89.80 |
| Locked in/Associated with Sulphides | 3.39 | 5.00 |
| Associated With Rock Forming Minerals | 1.41 | 1.00 |
| Other | 5.50 | 4.30 |

The results indicates that approximately 90% of the silver is amenable to cyanidation at a $P_{80}$ = 75 µm grind.

### 13.3.3 METALLURGICAL TEST WORK

#### *COMMINUTION TEST WORK*

SGS Vostok and TOMS completed comminution test work on a composite sample in order to determine the parameters required for the design of the comminution circuit.

The following tests were conducted:

- Bond Ball Mill Work Index ($BW_i$) (SGS Vostok)
- Bond Abrasion Index ($BA_i$) (SGS Vostok)
- Crusher Work Index ($CW_i$) (TOMS).

A summary of the comminution test results are shown in Table 13.14.

**Table 13.14 Summary of Comminution Results**

| Description | Unit | Test 1 | Test 2 |
|---|---|---|---|
| **Bond Ball Mill Index** | | | |
| Limiting Screen Size | µm | 75 | 106 |
| $F_{80}$ | µm | 2,540 | 2,540 |
| $P_{80}$ | µm | 58 | 84 |
| Work Index, $BW_i$ | kWh/t | 14.6 | 13.9 |
| **Bond Abrasion Index** | | | |
| Abrasion Index | g | 0.0392 | |
| **Crusher Work Index** | | | |
| Mean | kWh/t | 4.41 | |
| Standard Deviation | | 1.86 | |
| Minimum | | 1.68 | |
| Maximum | | 7.73 | |

The Bond Ball Mill Indices ($BW_i$ = 13.9 kWh/t and 14.6 kWh/t) indicate that the ore is categorised among the moderately hard range of the $BW_i$ scale. This means that fine grinding by ball milling could be an energy intensive operation.

The abrasion index of the Mangazeisky ore is moderately low and indicates a low wear rate of mill liners and media compared to similar silver projects.

The crusher work index is also categorised as moderately low, and indicates a lower crushing power requirement.

### GRAVITY CONCENTRATION TESTS

#### *Effect of Grind on Gravity Concentration*

The gravity concentration tests were carried out on a representative sample using the batch laboratory-scale Knelson KC-MD3 (Figure 13.9) test unit and Mozley Laboratory Separator. The Knelson concentrator acted as a primary gravity concentrator while the Mozely concentrator was used to clean the primary concentrates. These gravity tests were conducted at various grinds ($P_{80}$ = 212 µm, 106 µm, 75 µm, and 53 µm) in order to estimate the silver recovery at various grind sizes. A summary of the effect of grind gravity test results are shown in Table 13.15.

**Figure 13.9 Knelson KC-MD3 Laboratory Batch Test Unit**

**Table 13.15 Effect of Grind on Gravity Concentration**

| Feed Size ($P_{80}$ – µm) | Product | Mass (%) | Ag (g/t) | Ag Recovery (%) |
|---|---|---|---|---|
| 212 | Concentrate | 0.12 | 6,960 | 0.77 |
| | Middlings | 1.15 | 3,890 | 3.97 |
| | Tailings | 98.72 | 1,090 | 95.26 |
| 106 | Concentrate | 0.12 | 6,910 | 0.75 |
| | Middlings | 1.01 | 5,580 | 4.95 |
| | Tailings | 98.86 | 1,090 | 94.30 |
| 75 | Concentrate | 0.14 | 9,220 | 1.15 |
| | Middlings | 1.06 | 7,650 | 7.32 |
| | Tailings | 98.8 | 1,030 | 91.53 |
| 53 | Concentrate | 0.12 | 11,400 | 1.19 |
| | Middlings | 1.01 | 8,210 | 7.11 |
| | Tailings | 98.87 | 1,080 | 91.70 |

The results shown in Table 13.15 indicate that silver recovery gradually increased with finer grind up to $P_{80}$ = 75 µm grind size and remained unchanged with further grinding.

### *Gravity Recoverable Silver Test*

Gravity recoverable silver (GRS) tests were conducted using a centrifugal Knelson concentrator (KC-MD3) with stage grinding. The stage grinds included:

- Stage 1 – $P_{80}$ = 850 µm
- Stage 2 – $P_{80}$ = 150 µm
- Stage 3 – $P_{80}$ = 75 µm.

The GRS test was conducted on 20 kg ore charge with wash water added at 3.5 l/min. The results of the GRS tests are summarised in Table 13.16.

**Table 13.16 Summary of GRS test results**

| Feed Size ($P_{80}$ – µm) | Product | Mass (%) | Ag (g/t) | Ag Recovery (%) |
|---|---|---|---|---|
| 850 | Concentrate 1 | 0.55 | 2,460 | 1.13 |
| 150 | Concentrate 2 | 0.67 | 5,710 | 3.20 |
| 75 | Concentrate 3 | 0.59 | 7,700 | 3.78 |
| N/A | Total Concentrate | 1.81 | 5,368 | 8.10 |
| N/A | Tailings | 98.19 | 1,120 | 91.90 |

The results presented in Table 13.16 indicate that the overall gravity recoverable silver is approximately 8%. This is much lower than the gravity silver recovery reported in the historical test work completed by both laboratories.

These results suggest that gravity concentration as a pre-concentration step is not an attractive flowsheet solution based on the gravity silver recoveries. However, this aspect should be evaluated by taking in to account the overall silver recoveries and the capital and operating costs. Tetra Tech subsequently completed a high-level economic trade-off study, in order to evaluate the gravity concentration against ROM leach.

### *Bulk Gravity Concentration Tests*

Bulk gravity concentration tests were conducted in a laboratory Knelson concentrator, at a grind of $P_{80}$ = 75 µm, in order to prepare a feed sample for the leach tests.

The gravity concentrates were treated by intensive cyanidation in order to simulate the intensive leach reactor.

The gravity tails were then leached according to standard bottle roll cyanide leach procedures, with the objective of optimising the leach parameters (i.e. grind size, cyanide strength, pulp density and the addition of leach aids).

The summary of the bulk gravity concentration results are shown in Table 13.17.

**Table 13.17 Bulk Gravity Concentration Results**

| Product | Mass (%) | Ag (g/t) | Ag Recovery (%) |
|---|---|---|---|
| Concentrate | 1.1 | 8,550.0 | 7.9 |
| Tailings | 98.9 | 1,110.0 | 92.1 |
| Feed | 100.0 | 1,191.8 | 100.0 |

### *Intensive Cyanidation of Gravity Concentrates*

The gravity concentrates were tested for intensive cyanidation at two different sets of conditions as shown in Table 13.18.

**Table 13.18 Test Condition for Intensive Cyanidation**

| Parameter | Unit | Test 1 | Test 2 |
|---|---|---|---|
| Cyanide Concentration | g/l | 5 | 15 |
| pH | - | 10.5-11.0 | 10.5-11.0 |
| Grind Size ($P_{80}$) | µm | 75 | 25 |
| Leach Aid ($PbNO_3$) | g/t | - | 150 |
| Pre-aeration | h | 8 | 8 |
| Leach Time | h | 96 | 96 |

Note: $PbNO_3$ – lead nitrate

The summary of the silver recovery to solution are shown in Table 13.19.

**Table 13.19 Silver Recovery to Solution by Intensive Cyanidation**

| Test Reference | Recovery (%) |
|---|---|
| Test 1 | 72.9 |
| Test 2 | 98.0 |

The results indicate that a concentrate regrind of $P_{80}$ = 25 µm, a higher cyanide concentration of 15 g/l and the addition of leach aid has provided excellent silver extraction into solution.

These results clearly indicate that intensive cyanidation of gravity concentrates is an effective way of processing silver sulphide minerals which normally show very slow leach kinetics.

### *Cyanidation of Gravity Tails*

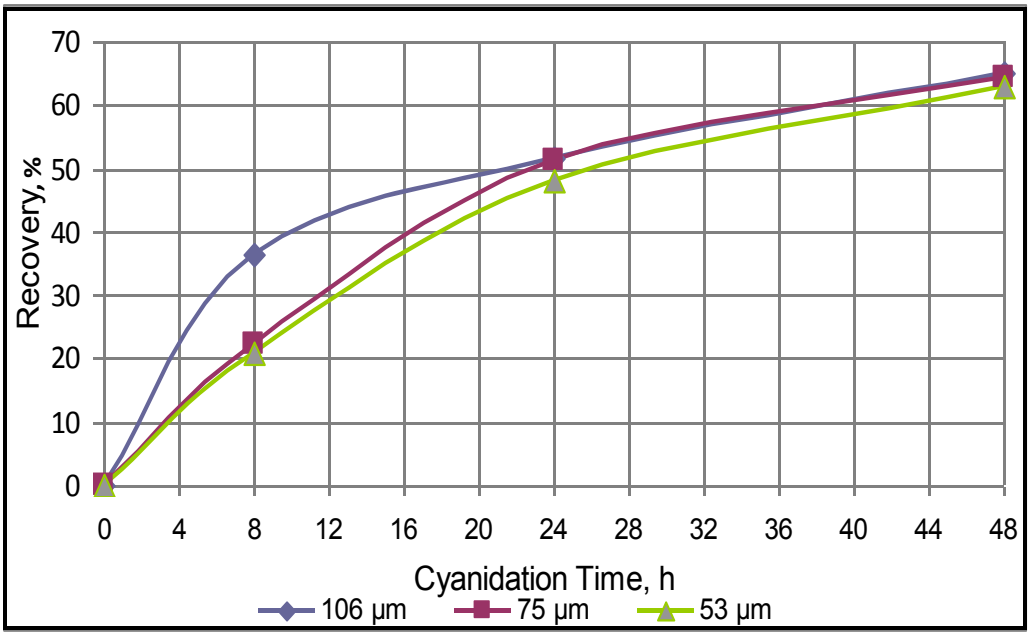
#### *Effect of Grind Tests*

Batch dissolution tests were carried out on the gravity tailings in order to evaluate the effect of grind on gold dissolution. Three grinds were tested: $P_{80}$ = 106 µm, 75 µm, and 53 µm.

The effect of grind leaches were run at standard conditions (i.e. 40% solids, 8 hour pre-conditioning period, 1.0 g/l sodium cyanide addition, and a pH range of 10.5 to 11.0). The slurries were leached for 48 hours at an ambient temperature.

A summary of the effect of grind leach tests are shown in Figure 13.10.

**Figure 13.10 Effect of Grind Leach Test Results**



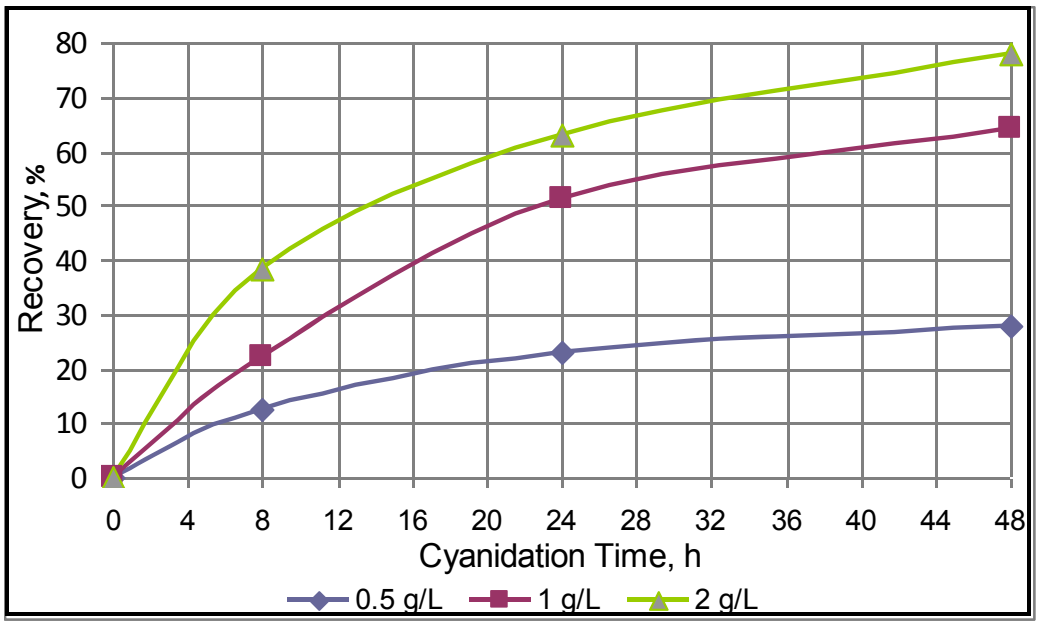

The results indicate that leach dissolution after 48 hours is almost identical for all three tests, but the leach kinetics are better for the coarser grind ($P_{80}$ = 106 µm) than the other two tests. This trend is unusual, but this may have happened as a result of cyanide insufficiency at finer grinds (i.e. at finer grinds liberated sulphide minerals might have competed with silver particles for cyanide).

The results also show that the leach did not reach equilibrium after 48 hours and the leach extraction curve continued to increase. In this context, firm conclusions about the effect of grind on the leach performance cannot be made based on these results. Thus, a grind size of $P_{80}$ = 75 µm was selected for the rest of the test work based on the diagnostic leach and wider industrial practice.

### *Effect of Cyanide Addition*

The effect of cyanide addition test was used to establish the optimum cyanide addition required for each sample in order to obtain maximum silver dissolution. The test was conducted at a $P_{80}$ = 75 µm grind using three different cyanide additions (0.5 g/l, 1.0 g/l, and 2.0 g/l). The summary of the results are presented in Figure 13.11.

**Figure 13.11 Effect of Cyanide Addition Leach Results**

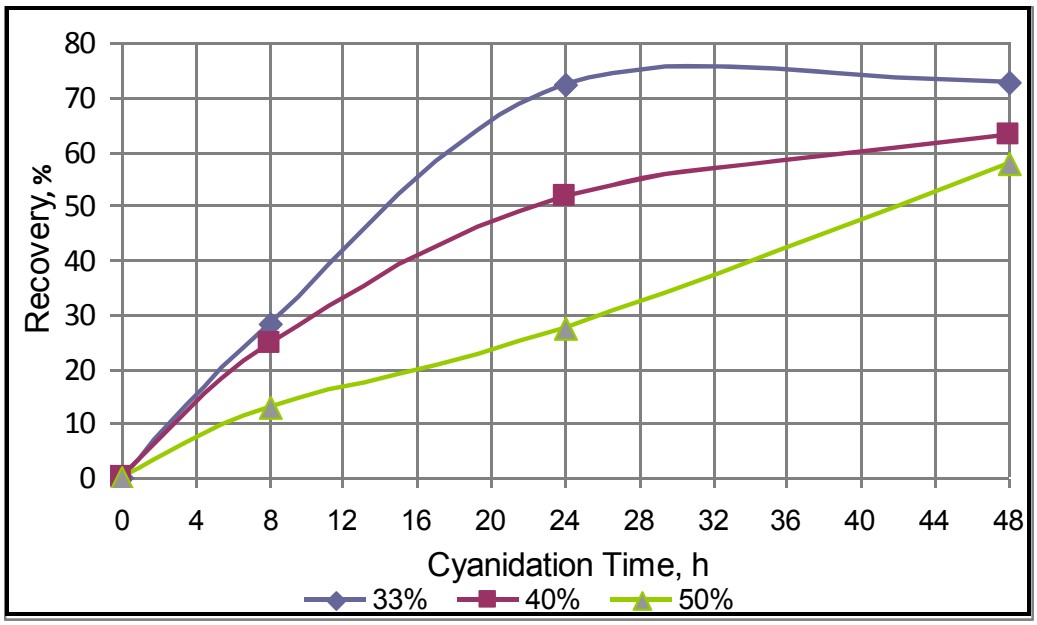



The results clearly indicate that both leach recovery and kinetics are better with higher cyanide concentration, but the leach has not stabilised after 48 hours. Based on these results, the cyanide concentration for gravity tails leach was selected as 2 g/l; however, this initial selection needs to be confirmed with further tests.

### *Effect of Pulp Density*

Three different pulp densities (33%, 40%, and 50%) were tested in order to establish the optimal pulp density for leaching. All other conditions remained as per standard conditions (i.e. $P_{80}$ = 75 µm grind, 8 hour pre-conditioning period, 1.0 g/l sodium cyanide addition, and a pH range of 10.5 to 11.0). The slurries were leached for 48 hours at an ambient temperature. A summary of the results is shown in Figure 13.12.

**Figure 13.12 Effect of Pulp Density Results**



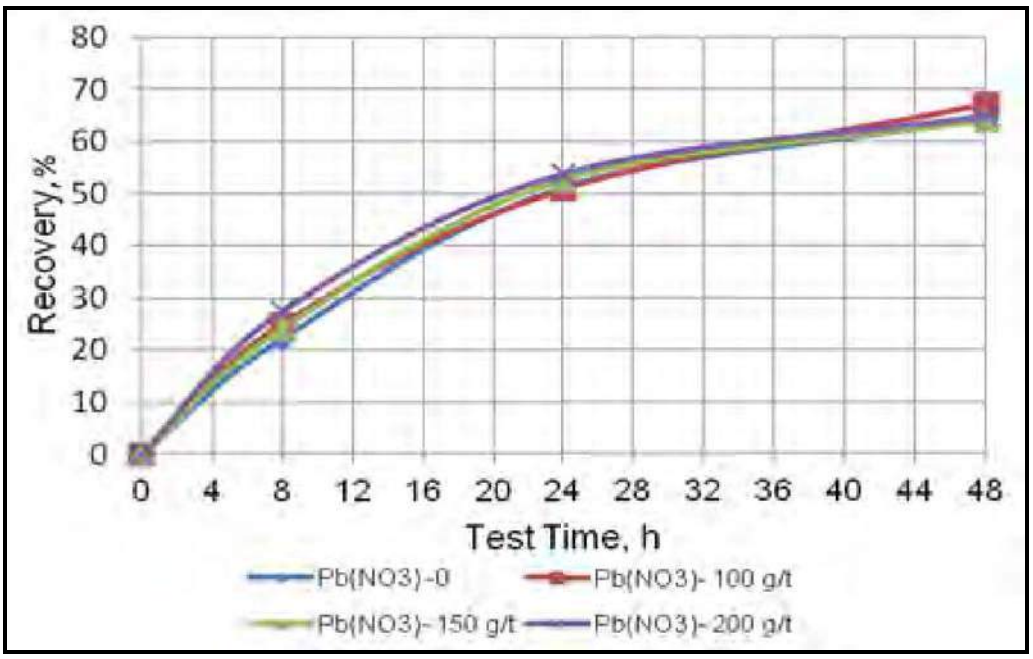

The results clearly indicate that both recovery and leach kinetics are better with lower pulp densities; however, the incremental recovery as a result of lower pulp density becomes smaller as the leach progresses.

Pulp density and cyanide concentration are interrelated to each other, and therefore no conclusions about pulp density can be made at this point.

### *Effect of Leach Aid (Silver Nitrate) Addition*

The effect of leach aid test was conducted at standard conditions (i.e. $P_{80}$ = 75 µm grind, 8 hour pre-conditioning period, 1.0 g/l sodium cyanide addition, 40% pulp density, and a pH range of 10.5 to 11.0) but with the addition of silver nitrate [$Pb(NO_3)_2$] during the pre-conditioning period as a leach aid. Three different rates (100 g/t, 150 g/t, and 200 g/t) of silver nitrate additions were tested along with a baseline test.

**Figure 13.13 Effect of Silver Nitrate Addition**

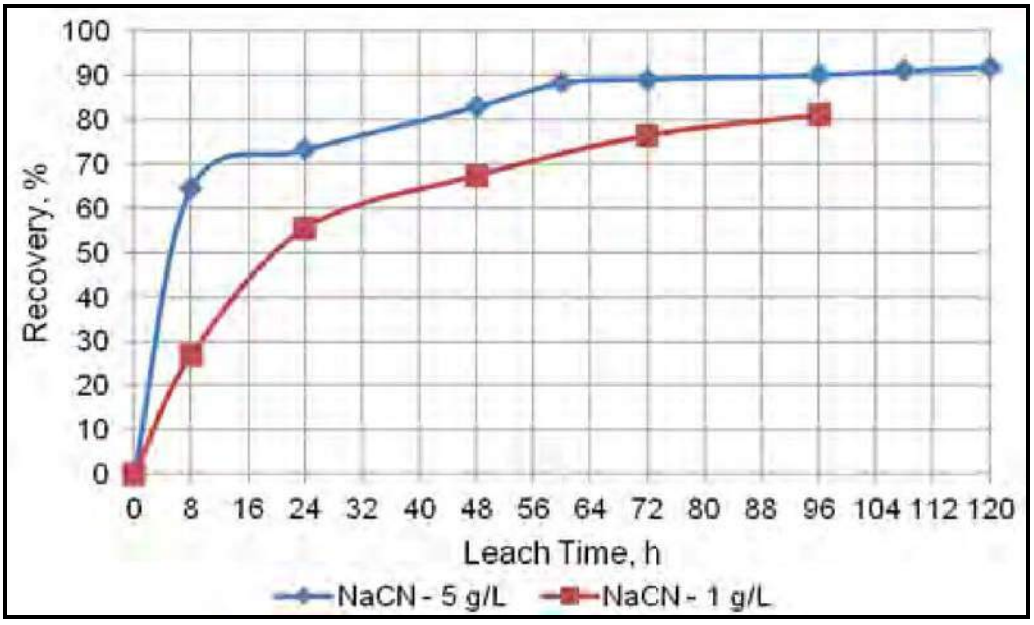



The results indicate that the silver nitrate addition has not influenced the overall recovery or leach kinetics.

### *Effect of Time/Leach Kinetics*

The effect of time test was conducted at two different cyanide concentrations (1 g/l and 5 g/l) for 96 hours and 120 hours in order to determine the optimal leach time. All other leach parameters remained as standard (i.e. $P_{80}$ = 75 µm grind, 8 hour pre-conditioning period, 40% pulp density, and a pH range of 10.5 to 11.0). The summary of the leach kinetics results are shown in Figure 13.14.

**Figure 13.14 Effect of Time Test/Leach Kinetics**



The effect of time results indicate that the leach performed at 5 g/l cyanide concentration reached equilibrium at approximately 56 to 72 h leach time. The final silver recovery to solution (after 120 hour leach) was reported at 91.85%.

The leach performed at 1 g/l of cyanide concentration had not reached equilibrium even after 96 hours of leach time. A silver recovery of 81.1% was achieved after this time.

In summary, the following observations can be made from the cyanidation of gravity tails:

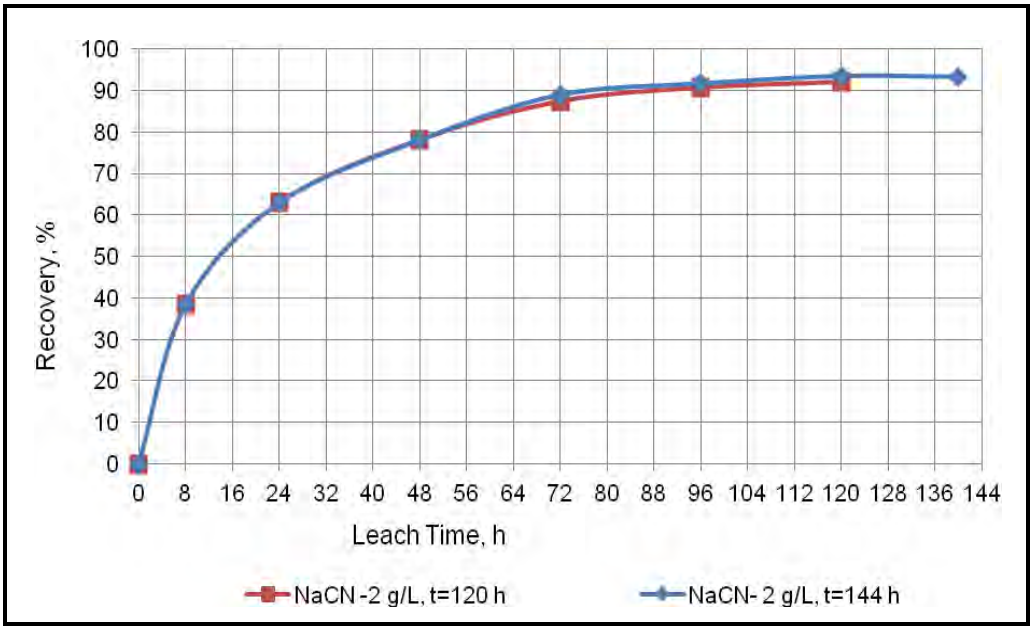
- The leach is not significantly influenced by the tested particle size distributions.
- The cyanide concentration has significant influence on the leach kinetics and silver recoveries. It is understood that 1 g/l is not sufficient and 5 g/l is more than sufficient. It appears 2 g/l is adequate cyanide concentration for leaching gravity tails.
- Leach kinetics is very slow and 48 hours is not sufficient in order for the leach to reach equilibrium.
- Pulp density has influenced the leach kinetics but the recovery after 48 hours of leach is not significantly different for the tested pulp densities.
- Silver nitrate addition has not influenced the leach kinetics or recoveries.

### *Re-leaching of Leach Tails*

Tetra Tech has proposed to conduct additional leach tests, where the dry solids residue from the 48 hour leach can be re-pulped and leached for extended leach time in order to reach higher silver recoveries. These tests were conducted from the sample retained from 2 g/l cyanide leach, all leach conditions other than retention time were as per standard (i.e. $P_{80}$ = 75 µm grind, cyanide concentration 2 g/l, 40% pulp density, and a pH range of 10.5 to 11.0). Two leach tests were conducted with increased leach retention time of an additional 72 hours and 96 hours. The overall leach retention time of these tests are equivalent to 120 hours and 144 h as a result of the additional leach time. The summary of the leach kinetics for increased retention time is shown in Figure 13.15.

The results shown in Figure 13.15 clearly indicate that the leach kinetics reach equilibrium at around 72 to 96 hours overall leach time. The silver recoveries for 72 hour and 96 hour leach were reported as 89%, 87.3% and 91.7%, 90.6% respectively.

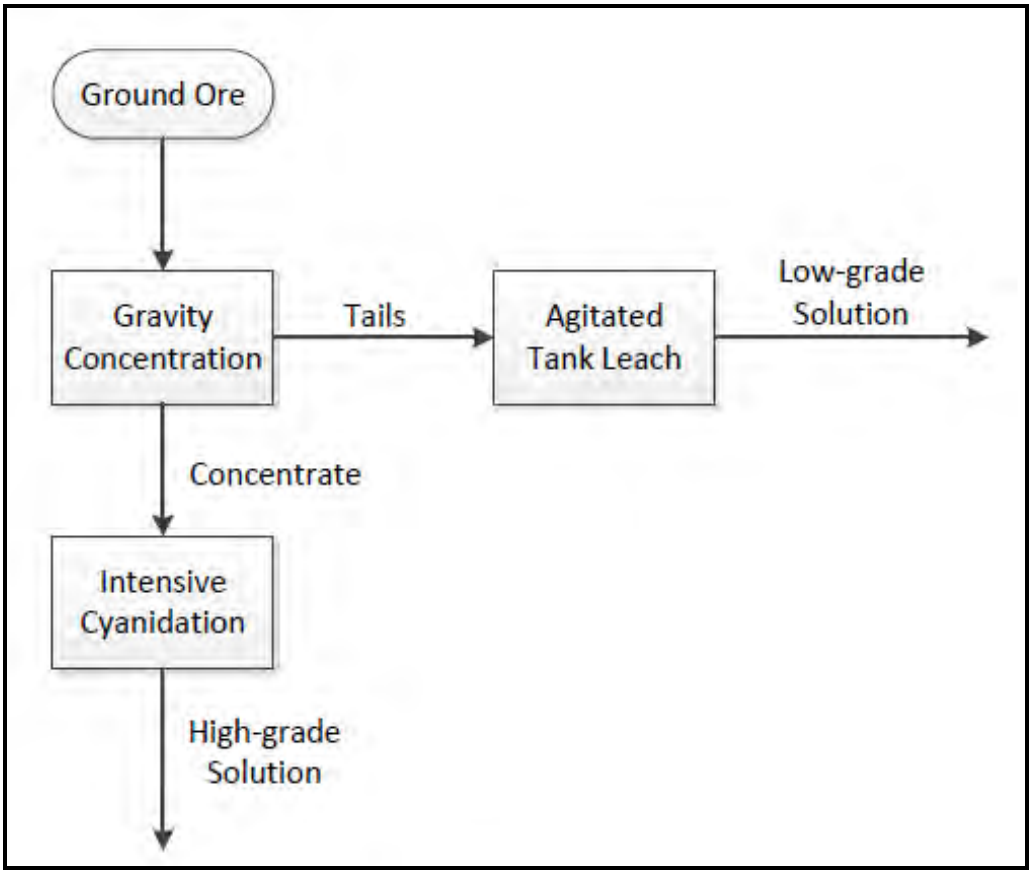
**Figure 13.15 Leach Kinetics for Re-leaching the Leach Tails**




### *Overall Recovery of Gravity Plus Leach Based Option*

The overall silver recovery of the gravity and leach based option was estimated based on a conceptual process block flow diagram as shown in Figure 13.16.

**Figure 13.16 Conceptual Block Flow Diagram for Gravity and Leach Based Option**



The total silver reported to both high grade and low grade solutions were estimated based on the test work results shown in this report and shown in Table 13.20.

**Table 13.20 Overall Silver Recovery Calculation for Gravity Based Flowsheet**

| Gravity Concentrates | Option A | Option B |
|---|---|---|
| Silver Recovery to Gravity Concentrate (%) | 7.9 | 7.9 |
| Silver Dissolution at Intensive Cyanidation (%) | 98.0 | 98.0 |
| Silver Reported to Intensive Leach Solution (%) | 7.7 | 7.7 |
| **Gravity Tails** | | |
| Silver Recovery to Gravity Tails (%) | 92.1 | 92.1 |
| Standard Leach Silver Dissolution* (%) | 88.2 | 91.2 |
| Silver Recovery to Standard Leach Solution (%) | 81.2 | 84.0 |
| **Overall Recovery** | | |
| Overall Silver Recovery to Solution | 88.9 | 91.7 |

Note: *Standard leach retention times of 72 hours and 96 hours assumed for Options A and B, respectively.

### *Flotation Test Work*

The flotation test work included initial optimisation tests followed by locked cycle flotation test work. In addition bulk flotation tests were conducted in order to prepare a sample for intensive cyanidation tests. All of the flotation tests were conducted in a laboratory bench scale Denver flotation cell (Figure 13.17).

**Figure 13.17 Laboratory Flotation Cell**

### *Grind Size Optimisation*

Effect of grind and reagent scouting tests were conducted as the primary step in flotation in order to establish the optimal flotation conditions. A summary of the effect of grind tests are shown in Table 13.21. Full details of the test conditions can be seen in the Appendix A.

**Table 13.21 Effect of Grind Flotation Test Results**

| Grind | Product | Mass (%) | Assay | | | Recovery | | |
|---|---|---|---|---|---|---|---|---|
| | | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| $P_{80}$ = 53 µm | Concentrate | 1.67 | 37,900 | 45.75 | 14.5 | 59.16 | 40.48 | 13.98 |
| | Middling 1 | 0.66 | 14,300 | 9.54 | 3.1 | 8.86 | 3.35 | 1.19 |
| | Middling 2 | 4.67 | 3,080 | 2.5 | 1.63 | 13.47 | 6.2 | 4.41 |
| | Scavenger Concentration 1 | 2.29 | 1,270 | 1.68 | 1.42 | 2.72 | 2.04 | 1.88 |
| | Scavenger Concentration 2 | 2.76 | 792 | 1.51 | 1.42 | 2.04 | 2.21 | 2.26 |
| | Tailings | 87.95 | 167 | 0.98 | 1.5 | 13.75 | 45.73 | 76.28 |
| $P_{80}$ = 44 µm | Concentrate | 1.98 | 40,300 | 45.98 | 14 | 71.11 | 45.27 | 15.03 |
| | Middling 1 | 0.64 | 14,600 | 7.5 | 2.28 | 8.33 | 2.39 | 0.79 |
| | Middling 2 | 6.93 | 1,120 | 1.41 | 1.53 | 6.94 | 4.87 | 5.77 |
| | Scavenger Concentration | 3.84 | 568 | 1.35 | 1.49 | 1.95 | 2.58 | 3.11 |
| | Tailings | 86.61 | 151 | 1.04 | 1.6 | 11.68 | 44.89 | 75.3 |

The results shown in Table 13.21 indicate that higher silver recoveries can be expected at a finer grind size of $P_{80}$ = 44 µm. Based on this result, this grind size was considered for the locked cycle test work.

### *Locked Cycle Test Work*

The summary of the locked cycle flotation test results are shown in Table 13.22.

**Table 13.22 Summary of Locked Cycle Test Results (Selective Flotation)**

| Product | Mass (%) | Assay | | | Recovery | | |
|---|---|---|---|---|---|---|---|
| | | Ag (g/t) | Pb (%) | Zn (%) | Ag (%) | Pb (%) | Zn (%) |
| Concentrate | 2.82 | 37,091 | 36.67 | 10.66 | 85.74 | 49.33 | 16.47 |
| Tailings | 97.18 | 179 | 1.09 | 1.57 | 14.26 | 50.67 | 83.53 |
| Feed | 100.00 | 1,220 | 2.10 | 1.83 | 100.00 | 100.00 | 100.00 |

The locked cycle test work results presented in Table 13.22 indicate that a flotation concentrate at 2.8% mass pull could potentially recover 85.7% of silver and 49.3% of lead.

It is important to note that not only lead and zinc recoveries are poor, but also the concentrates grades are much lower than required the minimum specifications for saleable lead and zinc concentrates.

### *Bulk Flotation Tests*

Bulk flotation tests were conducted at a grind of $P_{80}$ = 44 µm in order to prepare a feed sample for the intensive cyanidation tests.

The summary of the bulk flotation test results are shown in Table 13.23.

**Table 13.23 Summary of Bulk Flotation Results**

| Product | Mass (%) | Ag (g/t) | Ag Recovery (%) |
|---|---|---|---|
| Concentrate | 2.1 | 40,100.0 | 74.5 |
| Middlings | 1.1 | 7,378.1 | 6.6 |
| Tailings | 96.9 | 223.0 | 18.9 |
| Feed | 100.0 | 1,141.5 | 100.0 |

### *Intensive Cyanidation of Flotation Concentrates*

The flotation concentrates were tested for intensive cyanidation at two different sets of conditions (same conditions as intensive cyanidation of gravity concentrates) as shown in Table 13.18.

The summary of the silver recovery to solution are shown in Table 13.24.

**Table 13.24 Silver Recovery to Solution by Intensive Cyanidation**

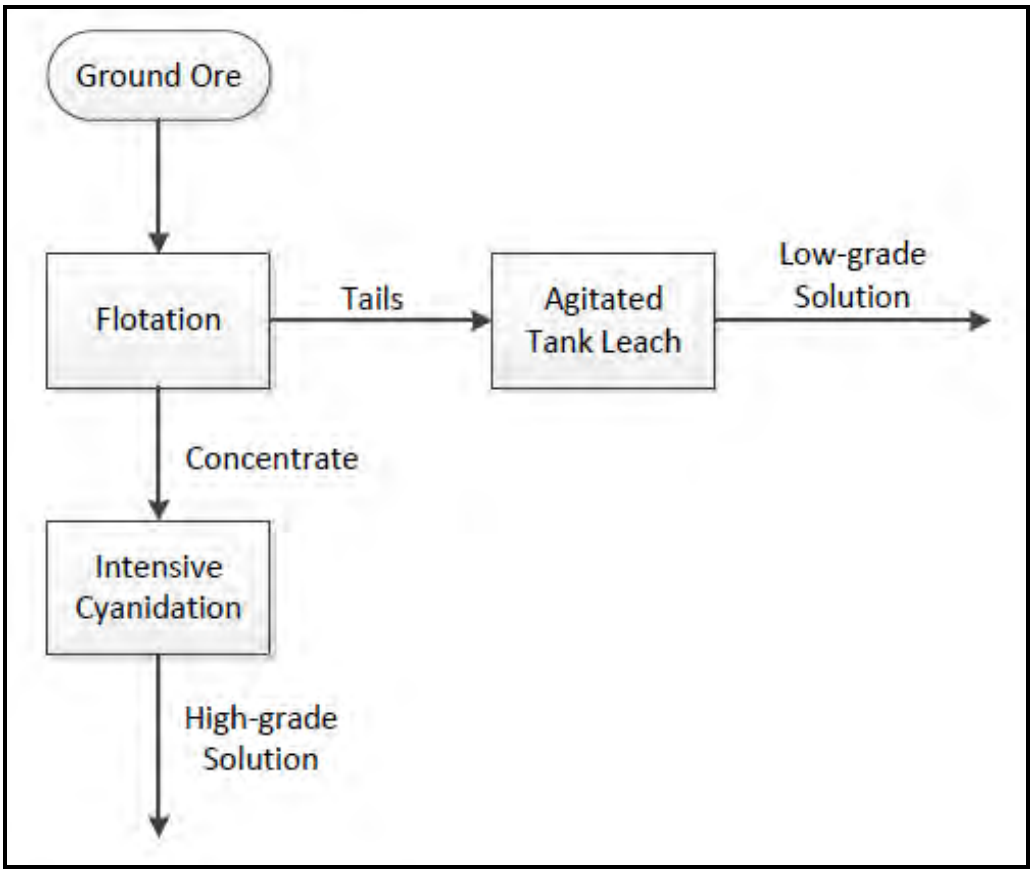
| Test Reference | Recovery (%) |
|---|---|
| Test 1 | 83.4 |
| Test 2 | 87.2 |

The results indicate that a concentrate regrind to $P_{80}$ = 25 µm, a higher cyanide concentration of 15 g/l and the addition of leach aid has not significantly influenced the silver recoveries into solution.

### *Overall Recovery by Flotation*

The overall silver recovery of the flotation plus leach based option was estimated based on a conceptual process block flow diagram as shown in Figure 13.18.

**Figure 13.18 Conceptual Block Flow Diagram for Flotation Option**




It is important to note that the flotation tails has not been tested for their leach behaviour. However, the leach recoveries of gravity tailings were assumed for the flotation tails, in order to make comparison between processing options.

The total silver reported to both high-grade and low-grade solutions was estimated based on the test work results shown in this report and as shown in Table 13.25.

**Table 13.25 Overall Silver Recovery of Flotation Based Option**

| | Calculation (%) |
|---|---|
| **Flotation Concentrates** | |
| Silver Recovery to Flotation Concentrate | 74.5 |
| Silver Dissolution on Intensive Cyanidation | 87.2 |
| Silver Reported to Intensive Leach Solution | 64.9 |
| **Gravity Tails** | |
| Silver Recovery to Gravity Tails | 25.6 |
| Standard Leach Silver Dissolution | 88.2 |
| Silver Recovery to Standard Leach Solution | 22.5 |
| **Overall Recovery** | |
| Overall Silver Recovery to Solution | 87.4 |

## HEAP LEACH TESTS

### Heap Leach Predictor Tests

Coarse ore bottle roll leach tests were conducted as heap leach predictor tests at three different crush sizes ($P_{80}$ = 20 mm, 10 mm, and 5 mm). The summary of the results are shown in Table 13.26.

**Table 13.26 Summary of Heap Leach Predictor Results**

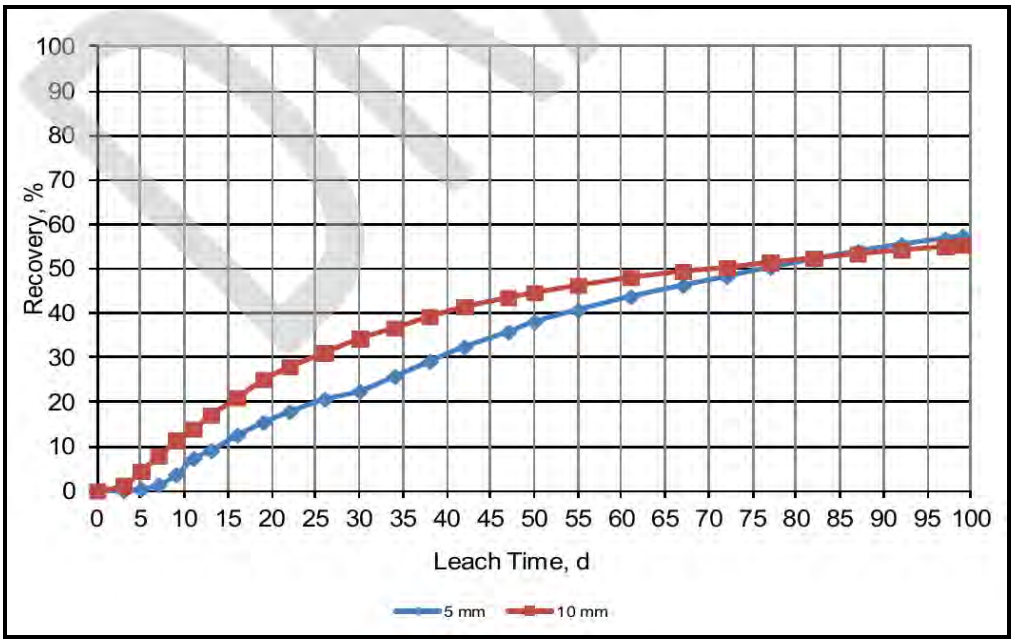
| Size ($P_{80}$-mm) | Recovery (%) |
|---|---|
| 20 | 39.12 |
| 10 | 47.83 |
| 5 | 61.19 |

The results clearly indicate that the leach recovery increases with finer particle size distribution. Based on this results, $P_{80}$ = 10 mm and 5 mm sizes were selected for column heap leach test work.

### Column Heap Leach Test

Colum heap leach tests were conducted in percolation columns with 110 mm diameter and 2,000 mm height according to standard procedure. Two different particle size distribution ($P_{80}$ = 10 mm and 5 mm) were considered for this test based on the heap leach predictor tests. The solution flow rate was kept at 0.003 l/s/m$^2$ throughout the test. The cyanide concentration of the solution and the pH of the column were kept at 0.2% and 10.5 to 11.5. The column heap leach tests were conducted for an extended duration of 100 days as a result of slower leach kinetics. The summary of the results are shown in Figure 13.19. Further details can be seen in the Appendix A.

**Figure 13.19 Heap Leach Test Results**



The results indicated that the expected silver recovery for heap leach after 100 days is approximately 56.5% and 59.4% for the $P_{80}$ = 10 mm and 5 mm grinds, respectively.

### ROM LEACH TESTS

#### Preliminary ROM Leach Tests

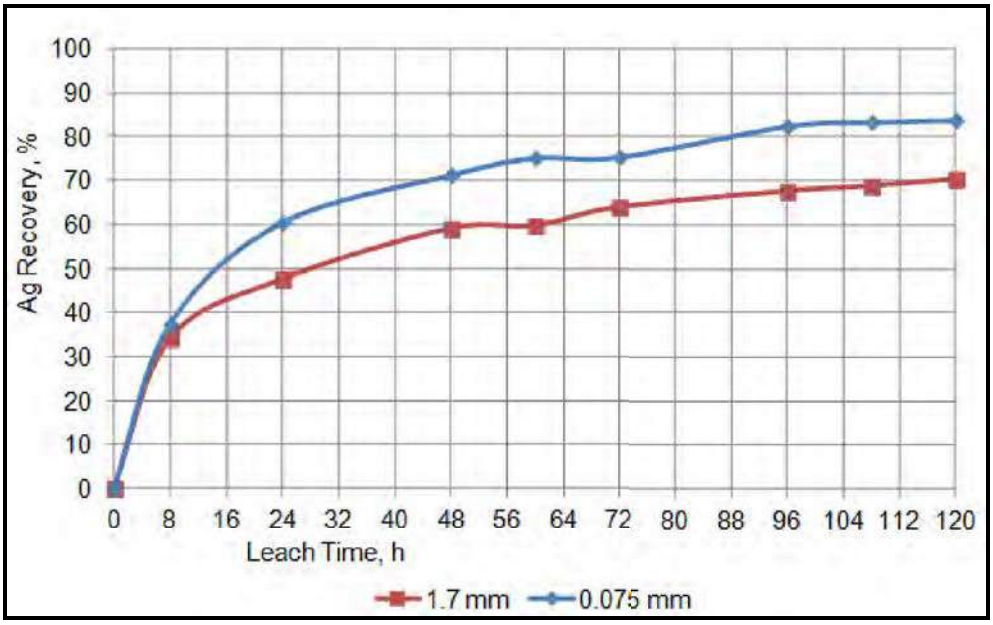
Preliminary ROM leach tests were conducted on two different particle size distributions ($P_{80}$ = 1.7 mm and 75 µm). The tests were conducted according to the conditions shown in Table 13.27.

**Table 13.27 ROM Leach Test Conditions**

| Parameter | Unit | Value |
|---|---|---|
| Cyanide Concentration | g/l | 2 |
| pH | - | 10.5 to 11.0 |
| Pre-aeration | h | 8 |
| Pulp Density | w/w % | 33 |
| Leach Time | h | 120 |

The summary of the preliminary ROM leach results are shown in Figure 13.20.

**Figure 13.20 Leach Kinetics of the Preliminary ROM Leach Test**




The results indicate that leach kinetics reach equilibrium after 96 hours for both particle size distributions.

SGS Vostok has reported final silver recoveries of 70.2% and 83.7% for the 1.7 mm and 75 µm tests, respectively.

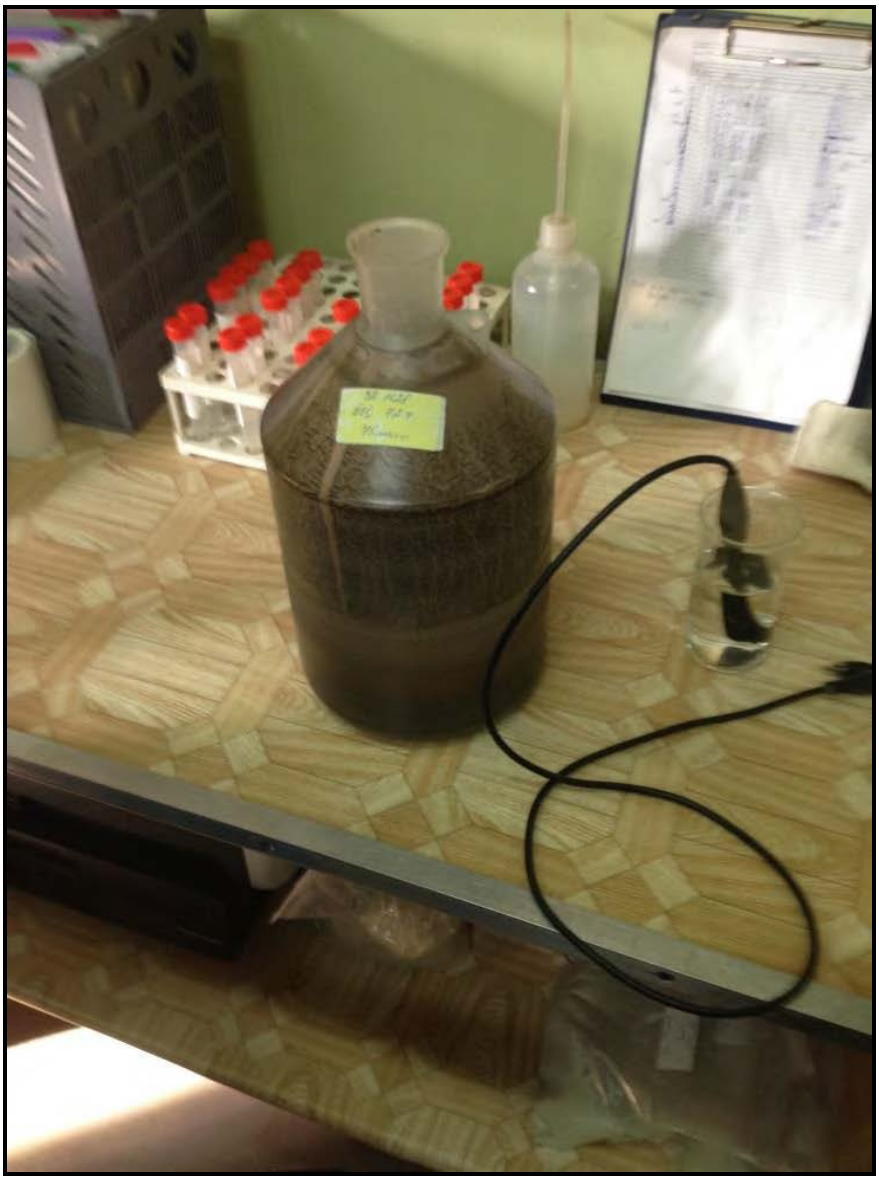
### *Reference Cyanide Leach Test*

In addition to the preliminary ROM leach test, a third leach was conducted as a reference test during a site visit by the author to the SGS Vostok laboratories. A 2 l test bottle (Figure 13.21) was used in this test work and the test was conducted according to conditions shown in Table 13.28.

**Table 13.28 Test Conditions for Reference Leach Test**

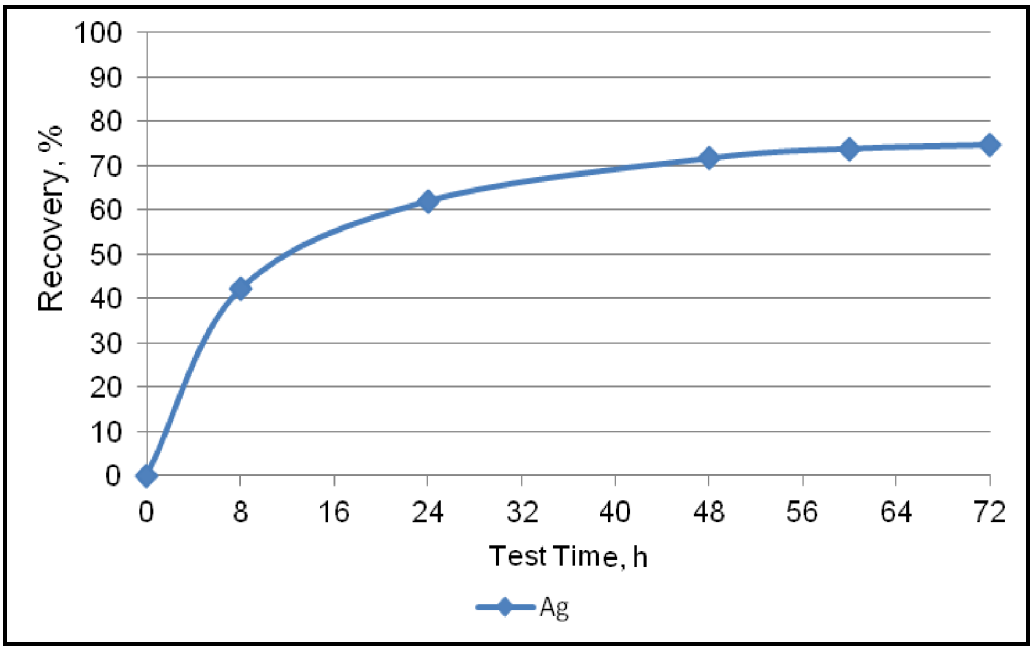
| Parameter | Unit | Value |
|---|---|---|
| Pre-aeration | h | 8 |
| pH | - | 10.5 |
| Cyanide Concentration | g/l | 2 |
| Pulp Density | w/w % | 40 |
| Leach Time | h | 72 |

**Figure 13.21 Bottle Roll Cyanide Leach Test Sample Preparation**



Summary of the reference leach test results are shown in Figure 13.22.

**Figure 13.22 Reference Leach Test Results**




SGS Vostok has reported the final silver recovery to solution as 74.8%.

The 74.8% recovery is comparable to the 72 hours recovery of the preliminary leach test of 75.2%.

These results, indicates that the optimal leach conditions for ROM ore and gravity tailings are not same despite the lower silver recovery to gravity concentrates. It appears some silver minerals and base metal sulphides that reported to the gravity concentrates have slowed the leach kinetics significantly during the ROM ore leach tests.

As a result of lower silver recoveries, a fresh set of ROM leach tests were conducted in order to optimise the leach conditions for the ROM ore.

### *ROM Leach Optimisation Tests*

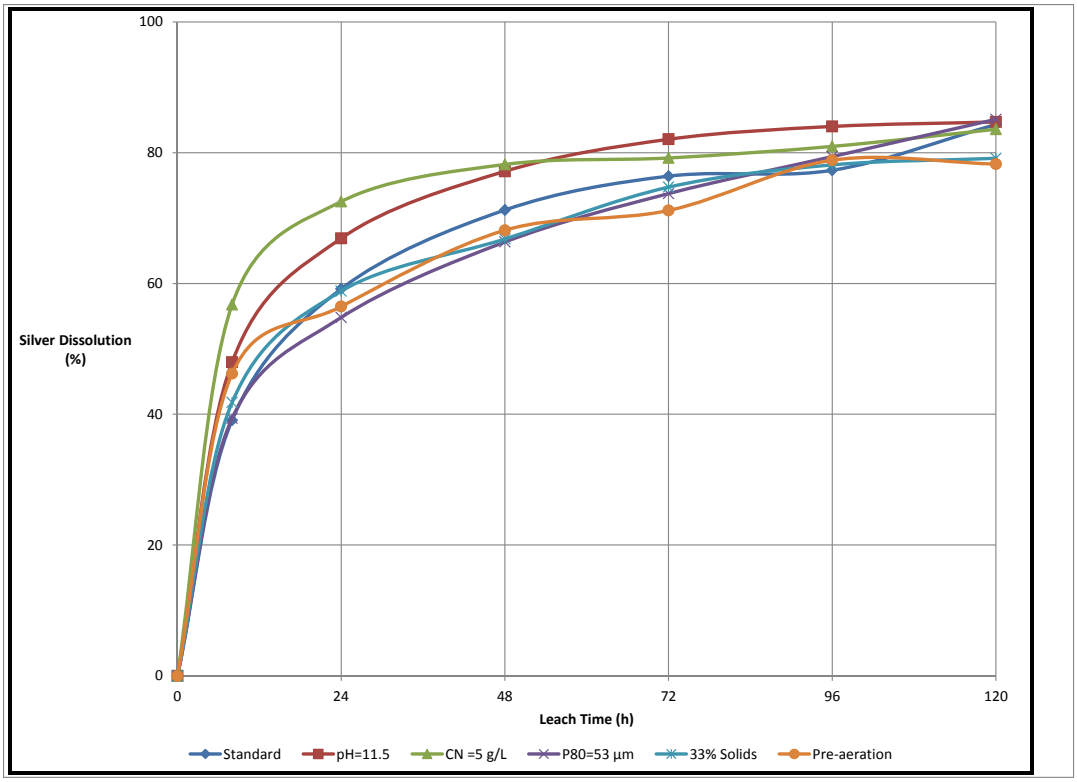
Six ROM leach tests were conducted in order to identify the leach parameters that increase the leach kinetics. The leach retention time for these tests was 120 hours. Other test conditions are shown in Table 13.29.

**Table 13.29 Test Conditions for ROM Leach Optimisation Tests**

| Test | Reference | pH | Cyanide Concentration (g/l) | Grind ($P_{80}$ -µm) | Pulp Density (w/w%) | Pre-aeration (h) | Leach Aid |
|---|---|---|---|---|---|---|---|
| 1 | Baseline | 10.5 | 2 | 75 | 40 | - | no |
| 2 | pH | 11.5 | 2 | 75 | 40 | - | no |
| 3 | Cyanide | 10.5 | 5 | 75 | 40 | - | no |
| 4 | Grind | 10.5 | 2 | 53 | 40 | - | no |
| 5 | Pulp Density | 10.5 | 2 | 75 | 33 | - | no |
| 6 | Pre-aeration | 10.5 | 2 | 75 | 40 | 8 | Peroxide |

The summary of the leach kinetics curves for the ROM leach optimisation tests are shown in Figure 13.23.

**Figure 13.23 Leach Kinetic Curves for the Optimisation Tests**




It appears that a higher cyanide concentration and higher pH has raised the leach kinetics significantly compared to the other tests. This could be possibly as a result of higher availability of free cyanide at those conditions. This pattern is in line with the general expectation of increased leach kinetics at higher availability of cyanide.

### *Direct Electrowinning Test Work*

Lab scale direct electrowinning test work was conducted by Electrometals LLC (2014) at the SGS Vostok premises with the following objectives:

- test the suitability of direct electro-winning technology for processing Mangazeisky and Vertikalny ores
- identify the typical tailings silver tenor and determine the operating parameters by depleting the solution
- obtain design parameters for large scale plant.

The sample for the test work was prepared by SGS Vostok by leaching a representative ore sample obtained by riffling. The silver concentration of the solution was reported as 798 ppm. Full details of the solution analysis can be seen in Appendix A

The bench scale direct electro-winning test equipment set up at SGS Vostok is shown in Figure 13.24.

**Figure 13.24 Direct Electrowinning Test in Progress at SGS Vostok**

The summary of the direct electro-winning results are shown in Table 13.30.

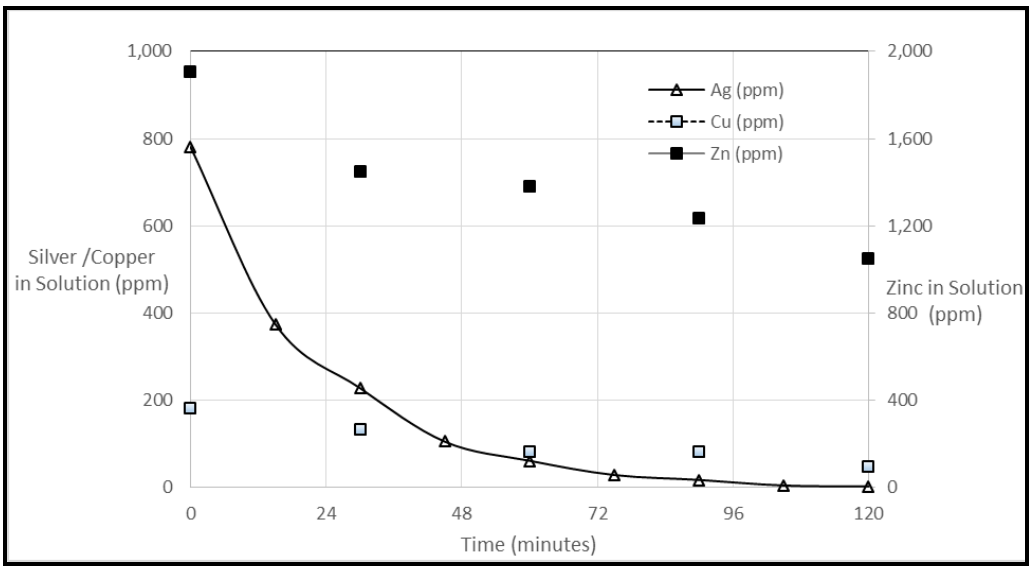
**Table 13.30 Summary of the Results from Direct Electrowinning Test Work**

| Time (h) | Trial 1 | Trial 2 | Trial 4 | Trial 5 | Trial 6 |
|---|---|---|---|---|---|
| | Ag (ppm) | | | | |
| 0.00 | 798 | 729 | 798 | 798 | 798 |
| 0.25 | 396 | 353 | N/A | N/A | N/A |
| 0.50 | 196 | 206 | 226 | 388 | 285 |
| 0.75 | 90 | 121 | N/A | N/A | N/A |
| 0.92 | 51 | 59 | N/A | N/A | N/A |
| 1.00 | N/A | 29 | 79 | 183 | 47 |
| 1.25 | N/A | 13 | N/A | 136 | N/A |
| 1.50 | N/A | 5 | 31 | 136 | 9.3 |
| 1.75 | N/A | 2 | | 53 | 5.2 |
| 2.00 | N/A | N/A | N/A | 31 | 3.6 |

The results shown in Table 13.30 demonstrate that the direct electro-winning depletes the silver from the solution to below 5 ppm in approximately 2 hours of time. Full details of the results can be seen in Appendix A.

Based on this results Tetra Tech plotted the depletion curves for silver, copper and zinc (Figure 13.25)

**Figure 13.25 Depletion Curves for Silver, Copper and Zinc**

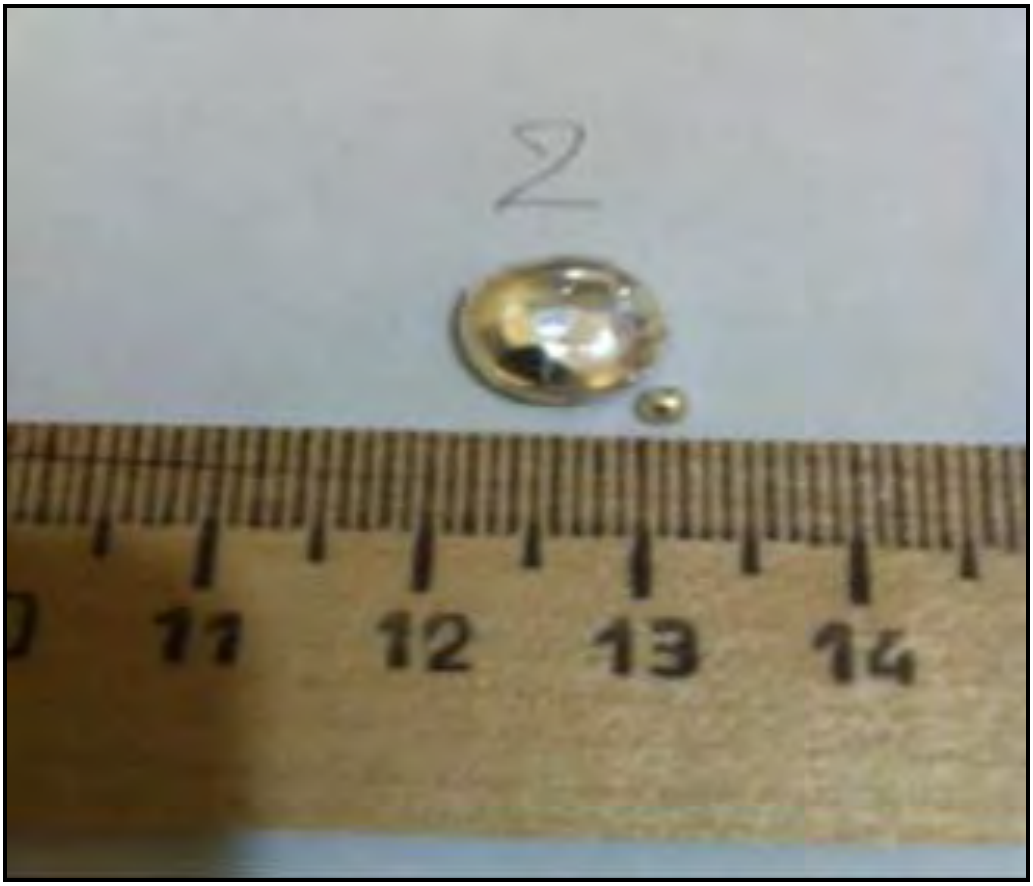



The depletion curves demonstrates that direct electro-winning can be utilized to selectively deplete silver while minimizing the base metals in to the final product. The selective depletion has also been confirmed by the excellent product quality (Table 13.31) obtained at the end of the test work.

The silver powder collected from the cathode and the silver button produced by melting the depleted silver powder are shown in Figure 13.26 and Figure 13.27.

**Figure 13.26 Silver Powder Collected from Cathode**

**Figure 13.27 Silver Button Produced by Melting the Deposited Silver**



The quality of the silver product was analysed in the laboratory and a summary of the analysis is shown in Table 13.31.

**Table 13.31 Silver Product Quality Analysis (%)**

| Metals | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 |
|---|---|---|---|---|---|---|
| Silver* | 99.9 | 99.9 | 99.9 | 99.9 | 99.9 | 99.9 |
| Arsenic | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| Cobalt | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Copper | 0.114 | 0.101 | 0.029 | 0.036 | 0.037 | 0.016 |
| Iron | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Nickel | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Lead | 0.028 | 0.016 | 0.089 | 0.025 | 0.023 | 0.044 |
| Zinc | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |

Note: *Silver by difference of elements tested

Based on the completed direct electrowinning test work, Tetra Tech concluded that this technology can be effectively utilised for the processing of Mangazeisky ore and excellent quality silver product can be produced on site.

### *Thickening Tests*

Thickening tests were performed on the cyanide leach residue slurry of the gravity tailings at a $P_{80}$=75 µm grind and 45% solids (w/w) pulp density. The test work included flocculent screening and optimization followed with further tests at the optimized conditions according to standard procedure.

A summary of the thickening test results with the specific thickener areas calculated by SGS Vostok according to Talmage and Fitch method are shown in Table 13.32.

Results and details of all other tests can be seen in Appendix A.

**Table 13.32 Thickening test results**

| Reagent Addition (g/t) | Final Percent Solids (%) | Thickener Underflow Unit Area ($m^2/t/d$) | Thickener Hydraulic Unit Area Overflow Capacity ($m^2/t/d$) | Settling Rate ($m^3/m^2/d$) | Total Suspended Solids (Overflow) (mg/l) |
|---|---|---|---|---|---|
| 0 | 69 | 0.309 | 0.314 | 1.4 | 24.0 |
| 10 | 69 | 0.258 | 0.111 | 4.5 | 22.3 |
| 20 | 69 | 0.205 | 0.050 | 15.3 | 19.8 |
| 30 | 69 | 0.191 | 0.026 | 23.5 | 18.0 |

Based on these results a unit thickener area of 0.191 $m^2/t/d$ was taken for thickener sizing along with a flocculent consumption of 30 g/t.

### *Filtration Tests*

Standard vacuum filtration tests were conducted on the cyanide leach residue slurry of the gravity tailings at a $P_{80}$ = 75 µm grind and 45% solids (w/w) pulp density. These tests were conducted with and without flocculants and the filter cake thickness

and moisture content were determined. The summary of the filtration tests results are shown in Table 13.33. Additional details of the filtration tests can be seen in the Appendix A.

**Table 13.33 Filtration Tests Results**

| Reagent Added (g/t) | Time (s) | | | Residue Thickness (mm) | Residue Moisture (%) | Specific Solids Throughput (kg/m²/h) | Specific Filtrate Throughput (l/m²/h) |
|---|---|---|---|---|---|---|---|
| | Residue Sampling | Residue Drying | Cycle | | | | |
| 0 | 60 | 420 | 1,080 | 19 | 32.28 | 115.79 | 71.29 |
| 30 | 320 | 130 | 450 | 19 | 32.16 | 251.92 | 184.97 |

It is clear from the data shown in Table 13.33 that flocculants addition helps to reduce the filtration time substantially as expected.

### *Cyanide Destruction Tests*

Batch Cyanide destruction tests were conducted with calcium hypochlorite as the detoxifying reagent. The summary of the results are shown in Table 13.34. Full details of the test conditions and results can be seen in the Appendix A.

**Table 13.34 Summary of Cyanide destruction test results**

| Stage | pH | Parameters | | | Assay (mg/l) | | | |
|---|---|---|---|---|---|---|---|---|
| | | Eh, mV | Added (kg/m³) | | | | | |
| | | Initial | $Ca(OCl)_2$ | CaO | $CN_{TOTAL}$ | $CN_{WAD}$ | CNS | Cl |
| Feed Pulp | 10.27 | 124 | - | - | 9649.9 | 427.34 | 334.2 | <50 |
| Stage I – 10 min | 10.63 | 330 | 12.5 | 6.14 | 476.1 | 11.9 | 69.8 | 178 |
| Stage II – 1 h | 10.5 | 530 | 8.6 | 0.82 | 5.54 | 0.67 | <1 | 213 |
| Stager III – 1 h | 10.7 | 610 | 5.0 | 0.74 | 2. 5 | <0.1 | <1 | 533 |

Notes: $Ca(OCl)_2$ – calcium hypochlorite; CaO – calcium oxide; $CN_{TOTAL}$ – total cyanide $CN_{WAD}$ – cyanide weak acid dissociable; Cl – chlorine

The test results indicated that hypochlorite treatment of the cyanide solution allows effective destruction of $CN_{TOTAL}$, $C_{WAD}$, and CNS.

### *Acid Base Accounting Tests*

Acid-base accounting (ABA) test was conducted on cyanide tailings to determine the acid-generating potential (AP) and neutralization potential (NP), and subsequently calculate the net neutralization potential (NNP). The results of the test work is expressed as the required mass of calcium carbonate ($CaCO_3$) for the neutralization of 1,000 tons of tailings. A summary of the ABA test results are shown in Table 13.35.

**Table 13.35 ABA Results**

| Sample | S total (%) | Potential (t of $CaCO_3$/1,000 tons) | | |
|---|---|---|---|---|
| | | AP | NP | NNP |
| CN Residue | 0.82 | 25.1 | 53.9 | 28.8 |

The results indicates that the tested sample is non-acid generating (NAG), but expressed a positive NNP of 28.8 t of calcium carbonate per 1,000 ton of samples.

## 13.4 LEACH VARIABILITY TEST WORK (TOMS)

### 13.4.1 SAMPLE BACKGROUND AND SELECTION

Tetra Tech has reviewed the sample inventory list provided by Silver Bear and selected 18 leach variability samples in order to provide variations of silver grade and oxidation state as reported in the geological Mineral Resource model. The preliminary selection was then reviewed and modified based on the sample delivery list to the laboratory. Tetra Tech's recommendation for sample selection is shown in Table 13.36. The sample inventory list provided by Silver Bear is located in Appendix A.

**Table 13.36 Tetra Tech Sample Recommendations for Leach Variability Test Work**

| | Hole ID | Indicated Silver Grade (g/t) |
|---|---|---|
| **Oxides** | | |
| Low Grade | V13-22 | 216 |
| | V13-24 | 221 |
| Medium Grade | V13-10 | 652 |
| | V13-14 | 759 |
| High Grade | V07-004 | 971 |
| | V13-11 | 1,323 |
| | **Hole ID** | **Head Grade (g/t)** |
| **Transition** | | |
| Low Grade | V09-150 | 232 |
| | V07-015 | 239 |
| Medium Grade | V13-11 | 525 |
| | V09-152 | 756 |
| High Grade | V09-156 | 1,214 |
| | V13-22-2 | 3,072 |

*table continues...*

| | Hole ID | Head Grade (g/t) |
|---|---|---|
| **Primary** | | |
| Low Grade | V13-11-3 | 11.9 |
| | V08-075 | 338.5 |
| Medium Grade | V08-080 | 671 |
| | V13-10-2 | 1488 |
| High Grade | V08-087 | 933.5 |

Note: *The oxidation status of some of the selected samples were reassigned based on the laboratory sulphur analysis, details of this analysis can be seen in Appendix A.

### 13.4.2 Sample Preparation

The selected variability leach samples were prepared by two stage closed circuit crushing and riffling in the laboratory in order to produce a representative sub-sample of -0.5 mm. The subsample of -0.5 mm size was the ground to $P_{80}$ 75 µm mixed, and then representative samples were taken for silver assays, sulphur phase analysis, and leach tests.

### 13.4.3 Head Assays

The silver head assays as reported by the laboratory are shown in Table 13.37.

**Table 13.37 Silver Head Assays**

| Sample No. | Sample Marking | Ag Grade (g/t) |
|---|---|---|
| 1 | V07-004 | 337 |
| 2 | V07-015 | 669 |
| 3 | V08-075 | 504 |
| 4 | V08-087 | 266 |
| 5 | V09-150 | 149 |
| 6 | V13-14 | 1,144 |
| 7 | V13-24 | 132 |
| 8 | V08-080 | 442 |
| 9 | V09-152 | 1,060 |
| 10 | V09-156 | 2,219 |
| 11 | V13-10-1 | 89. |
| 12 | V13-10-2 | 1,488 |
| 13 | V13-11-3 | 11.9 |
| 14 | V13-11-1 | 498 |
| 15 | V13-11-2 | 1,830 |
| 16 | V13-22-1 | 695 |
| 17 | V13-22-2 | 3,072 |

Note: It was reported by TOMS that one of the recommended sample was not available for test work due to sample shipping errors.

### 13.4.4 LEACH TESTS

Agitated leach tests were conducted in the laboratory (Figure 13.28) according to the conditions specified in Table 13.38. These conditions were selected based on the leach optimisation test work completed in SGS Vostok in 2014.

**Figure 13.28 Agitated Leach Test in Progress**

**Table 13.38 Leach Test Conditions**

| Parameter | Units | Value |
|---|---|---|
| NaCN Concentration | ppm | 2,000 |
| pH | – | 11.5 |
| Slurry Density at Cyanidation | % solids | 40 |
| Leach Retention Time | h | 120 |
| Grind ($P_{80}$) | µm | 75 |

### 13.4.5 RESULTS

The leach results for the oxidized, transition and primary ore samples are shown in Table 13.39, Table 13.40, and Table 13.41.

**Table 13.39 Leach Results for Oxidized Samples**

| Sample Reference | Ag Grade (g/t) | | Ag Dissolution (%) |
|---|---|---|---|
| | Head | Tails | |
| V07-004 | 337 | 96.1 | 71.48 |
| V13-14 | 1,144 | 174 | 84.79 |
| V13-24 | 132 | 8.74 | 93.38 |
| V13-10-1 | 89.2 | 24.5 | 72.53 |
| V13-10-2 | 1,488 | 215 | 85.55 |
| V13-22-2 | 3,072 | 394 | 87.17 |
| V13-11-2 | 1,830 | 416 | 77.27 |
| V13-11-3 | 11.9 | 1.51 | 87.31 |
| Mean | | | 82.4 |
| Standard Deviation | | | 7.8 |

**Table 13.40 Leach Results for Transition Samples**

| Sample Reference | Ag Grade (g/t) | | Ag Dissolution (%) |
|---|---|---|---|
| | Head | Tails | |
| V07-015 | 669 | 538 | 19.58 |
| V09-150 | 149 | 58.6 | 60.67 |
| V09-152 | 1,060 | 874 | 17.55 |
| V09-156 | 2,219 | 1769 | 20.28 |
| V13-22-1 | 695 | 169 | 75.68 |
| V13-11-1 | 498 | 135 | 72.89 |
| Mean | | | 44.4 |
| Standard Deviation | | | 28.2 |

**Table 13.41 Leach Results for Primary Samples**

| Sample Reference | Ag Grade (g/t) | | Ag Dissolution (%) |
|---|---|---|---|
| | Head | Tails | |
| V08-075 | 504 | 292 | 42.06 |
| V08-087 | 266 | 231 | 13.16 |
| V08-080 | 442 | 303 | 31.45 |
| Mean | | | 28.9 |
| Standard Deviation | | | 14.6 |

The results clearly indicate that the amenability to cyanidation varies significantly between the tested samples. The silver dissolution in cyanide ranges from 13.16% (primary ore, Table 13.41) to 93.38% (oxide ore, Table 13.39). The average silver dissolution for oxide ore (82.4%) is comparable to the silver dissolutions reported by SGS Vostok test work in 2014. However the average dissolutions for transition and primary ore types are 44.4% and 28.9%. The lower dissolutions clearly indicate that the leaching conditions for the transition and primary ore types are not similar to the oxide ore. It can be concluded from this test work that the primary ore leach requires additional optimization work.

## 13.5 PRIMARY ORE TEST WORK (TOMS)

### 13.5.1 SAMPLE BACKGROUND

Tetra Tech was not involved with the sample selection for the primary ore metallurgical test work completed by TOMS, but did review the sample lists provided by Silver Bear. It is understood that the 27 test work samples were collected from 11 drillholes within the mineralization to represent the primary ore. It appears that the drillholes have covered the entire mineralization which could be mined over the LOM. The selected samples were sent to TOMS as a single composite sample weighing approximately 89 kg with an average silver head grade of 368.5 g/t. The sample selection list provided by Silver Bear is shown in Table 13.42.

**Table 13.42 Sample List for Primary Ore Composite**

| Sample ID | Hole ID | From (m) | To (m) | Ag (g/t) |
|---|---|---|---|---|
| 9675 | V14-02 | 85.30 | 86.40 | 220 |
| 9675 | V14-03 | 68.60 | 69.40 | 366 |
| 9650 | V14-06 | 52.50 | 53.15 | 77.2 |
| 9650 | V14-06 | 53.15 | 54.00 | 152 |
| 9650 | V14-06 | 54.00 | 54.95 | 218 |
| 9650 | V14-06 | 54.95 | 55.50 | 880 |
| 9650 | V14-06 | 55.50 | 56.20 | 116 |
| 9175 | V14-09 | 107.40 | 108.05 | 222 |
| 9175 | V14-09 | 108.05 | 109.10 | 191 |
| 9175 | V14-09 | 109.10 | 110.10 | 147 |
| 9175 | V14-09 | 110.10 | 111.10 | 177 |
| 9150 | V14-14 | 42.00 | 43.00 | 203 |
| 9150 | V14-16 | 169.00 | 169.25 | 718 |
| 10050 | V14-19 | 177.00 | 177.70 | 1594 |
| 10050 | V14-19 | 177.70 | 178.40 | 361 |
| 10050 | V14-19 | 178.40 | 179.20 | 136 |
| 10050 | V14-19 | 179.20 | 179.40 | 226 |
| 9950 | V14-21 | 145.40 | 145.80 | 431 |
| 9950 | V14-21 | 145.80 | 146.00 | 208 |
| 9950 | V14-21 | 146.00 | 146.30 | 757 |
| 9950 | V14-21 | 146.30 | 147.30 | 122 |
| 9350 | V09-150БД | 26.50 | 27.50 | 265 |

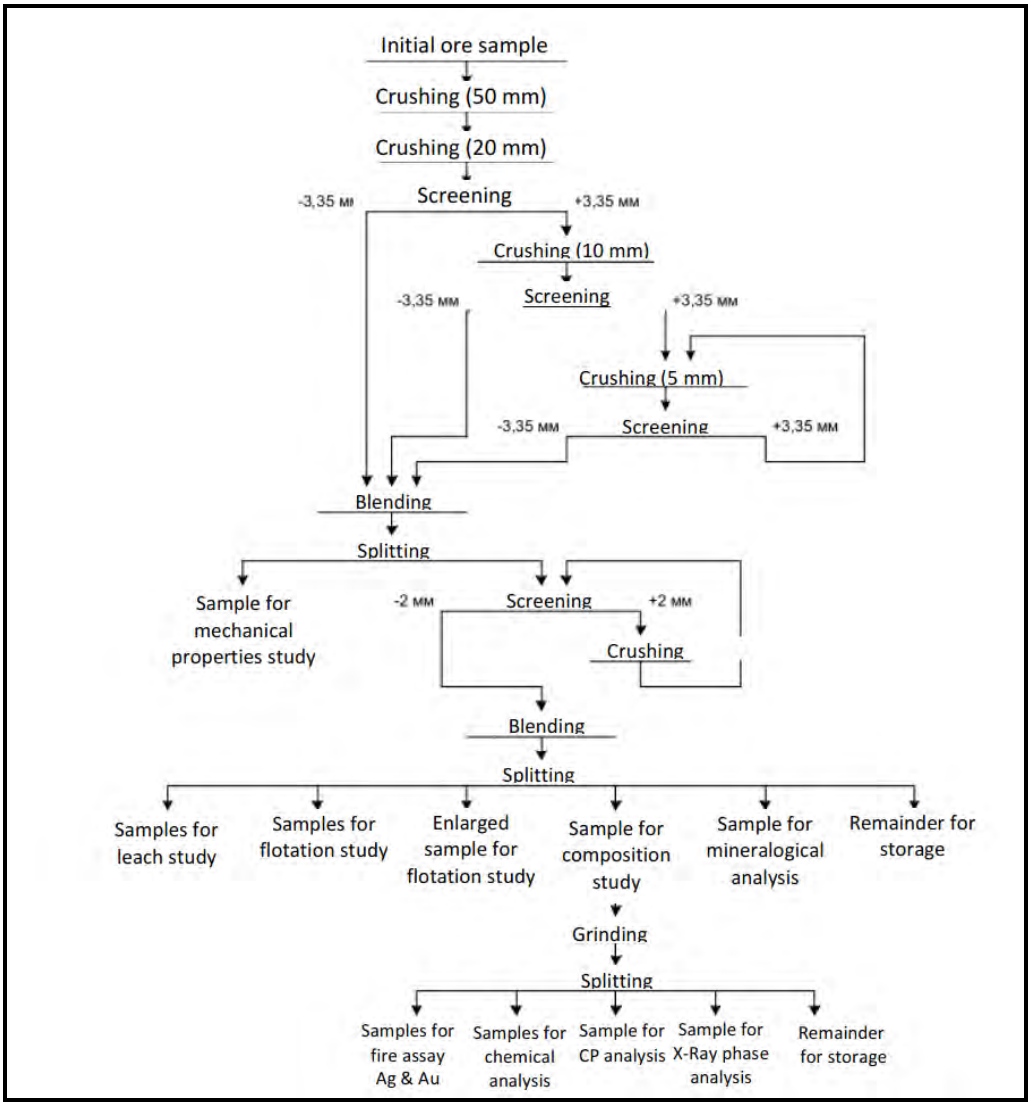
*table continues...*

| Sample ID | Hole ID | From (m) | To (m) | Ag (g/t) |
|---|---|---|---|---|
| 9350 | V09-150БД | 27.50 | 28.50 | 527 |
| 9350 | V09-150БД | 28.50 | 29.00 | 205 |

### 13.5.2 Sample Preparation

The composite sample was prepared by crushing, screening and riffling for various tests as shown in Figure 13.29.

**Figure 13.29 Sample Preparation Flowsheet**




### 13.5.3 Head Assays

TOMS analysed the head sample for silver, gold, copper, lead, and zinc assays, and conducted a whole rock analysis for all other major elements. A summary of the assay and whole rock analyses are shown in Table 13.43.

**Table 13.43 Head Assays of the Primary Ore Composite**

| Element | Sample Grade (g/t) | | | | Average Grade (g/t) |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| Silver | 366 | 379 | 361 | 379 | 371 |
| Gold | 0.141 | 0.115 | - | - | 0.128 |

**Table 13.44 Whole Rock Analysis of the Primary Ore Composite**

| Element, Component | Grade (%) | Element, Component | Grade (%) |
|---|---|---|---|
| $SiO_2$ | 33.1 | Zn | 3.56 |
| $AL_2O_3$ | 7.33 | Pb | 3.25 |
| CaO | 0.56 | Cи | 0.089 |
| $K_2O$ | 2.18 | Ni | 0.0013 |
| $Na_2O$ | <1.0 | Sb | 0.048 |
| MgO | 1.27 | As | 0.94 |
| MnO | 3.32 | Cd | 0.023 |
| $P_2O_5$ | 0.089 | Cr | 0.006 |
| $TiO_2$ | 0.35 | Co | 0.0015 |
| $C_{gen}$ | 4.05 | Mo | <0.001 |
| $CO_2$ | 12.3 | Ba | 0.022 |
| $Fe_{gen}$ | 19.6 | Sn | 0.031 |
| Fe(S) | 2.53 | Sr | 0.0067 |
| $Fe_{oxide}$ | 17.07 | W | <0.005 |
| $Fe_{hydroxide}$ | 1.18 | Bi | <0.005 |
| $S_{gen}$ | 4.59 | Au (g/t) | 0.128 |
| $S_{sulphate}$ | <0.25 | Ag, (g/t) | 371 |

## 13.5.4 MINERALOGICAL ANALYSIS

TOMS has undertaken a mineralogical analysis by optical microscope analysis, and estimated the quantities of each mineral by basic calculations of chemical composition of the sample. The summary of TOMS mineralogical analysis is shown in Table 13.45.

**Table 13.45 Mineralogical Analysis**

| Mineral | Estimated Mass Fraction (%) |
|---|---|
| **Rock Forming Minerals** | |
| Quartz | 25.0 |
| Siderite | 34.0 |
| Mica | 20.0 |
| **Ore Forming minerals** | |
| Galena | 4.0 |
| Sphalerite | 5.0 |
| Arsenopyrite | 2.0 |
| Pyrite | 4.0 |
| Iron Hydroxides | 2.0 |
| Pyrolusite, Psilomelane | 4.0 |
| **Total** | **100.0** |

### 13.5.5 Bond Ball Mil Index test

TOMS completed a Bond ball mill work index test in order to determine the parameters required for the design of the comminution circuit. The summary of the results are shown in Table 13.46.

**Table 13.46 Bond Ball Mill Index Test Results**

| Description | Unit | Results |
|---|---|---|
| Limiting Screen Size | µm | 38 |
| $F_{80}$ | µm | 2,434 |
| $P_{80}$ | µm | 33 |
| Work Index, $BW_i$ | kWh/t | 19.0 |

The Bond ball mill index ($BW_i$ = 19.0 kWh/t) indicate that the ore is categorised amongst the hardest range of the Bond ball mill expert scale. This means that fine grinding of primary ore by ball milling could be an energy intensive operation.

### 13.5.6 Cyanide Leach Tests

TOMS has conducted a series of agitated tank leach tests (Figure 13.30) in order to optimize the leach conditions for primary ore.

**Figure 13.30 Agitated Tank Leach Tests**

### *Baseline Test*

The first leach test was conducted as a baseline under the optimized conditions for oxides ore but with saturated dissolved oxygen levels. The summary of the baseline leach test conditions are shown in Table 13.47.

**Table 13.47 Baseline Leach Test Conditions**

| Parameter | Unit | Value |
|---|---|---|
| Grinding size $P_{80}$ | µm | 75 |
| pH | - | 11.5 |
| Concentration Cyanide-ions | mg/l | 2000 |
| Concentration DO | mg/l | Around 8.4-8.6 |
| Pulp Aeration | - | Compressed air |
| Pulp Density | % solids | 40 |
| Leaching Duration | h | 120 |
| Solution Sampling | h (from start of test) | 4, 8, 24, 48, 72, 96, 120 |

The summary of the baseline leach test results are shown in Table 13.48.

**Table 13.48 Baseline Leach Test Results**

| Test Reference | Head Grade (Ag g/t) | Tails Grade, (Ag g/t) | Dissolution (Ag %) |
|---|---|---|---|
| Baseline | 371 | 262 | 29.38 |

The poor leach dissolution (29.4%) demonstrates that the leach conditions need further optimization.

### *Grind Size Optimization*

Grind size optimization tests were performed on three grinds ($P_{80}$ 75 µm, $P_{80}$ 53 µm, and $P_{80}$ 38 µm). Cyanide concentration was maintained at 10,000 mg/l throughout the testing. All other test parameters were similar to the base line test parameters (Table 13.47).

The summary of the grind size optimization leach test results are shown in Table 13.49.

**Table 13.49 Grind Size Optimization Results**

| Grind Size ($P_{80}$-µm) | Head Grade (Ag g/t) | Tails Grade (Ag g/t) | Dissolution (Ag %) |
|---|---|---|---|
| 75 | 371 | 199.5 | 46.23 |
| 53 | | 179.5 | 51.62 |
| 38 | | 167 | 54.99 |

The results indicate that the silver dissolution steadily increases with fine grinds, and based on this, the grind size for the next stage of testing was selected as $P_{80}$ = 25 µm in order to maximize the silver dissolution.

### *Cyanide Concentration Optimization*

Cyanide concentrate optimization tests were performed on three different cyanide concentrations (2,000 mg/l, 5,000 mg/l, and 10,000 mg/l). The grind size was kept constant at $P_{80}$ = 25 µm for all three tests. All other test parameters used similar baseline test parameters.

The summary of the cyanide concentration leach test results are shown in Table 13.50.

**Table 13.50 Cyanide Concentration Optimization Results**

| Cyanide Concentration (mg/l) | Head Grade (Ag g/t) | Tails Grade (Ag g/t) | Dissolution (Ag %) |
|---|---|---|---|
| 2,000 | 371 | 211 | 43.13 |
| 5,000 | | 143.5 | 61.32 |
| 10,000 | | 107.5 | 71.02 |

The results indicate that the leach dissolution increases with the increase in cyanide concentration. Based on this results a cyanide concentration of 10,000 mg/l was selected for the final leach test under optimized conditions.

### *Leach Test Under Optimized Conditions*

The leach results indicate that the leach dissolution steadily increases with both finer grind and higher cyanide concentration. The results also demonstrated that the primary ore leach kinetics are extremely slow and the leach curves steadily progress even after 120 hours. It was clear that further work is required to adequately optimise the leach conditions. However the project schedule and the lack of sample availability of sample for additional test work has prevented additional optimisation work. Therfore, the leach test was conducted under the optimised test conditions shown in Table 13.51.

**Table 13.51 Leach Test Condition for Optimized Condition Test**

| Parameter | Unit | Value |
|---|---|---|
| Grinding size $P_{80}$ | µm | 25 |
| pH | - | 11.5 |
| Concentration Cyanide-ions | mg/l | 10,000 |
| Concentration DO | mg/l | Around 8.4-8.8 |
| Pulp Aeration | - | Compressed air |
| Pulp Density | % solids | 30 |
| Leaching Duration | h | 120 |
| Solution Sampling | h (from start of test) | 2, 4, 8, 24, 48, 72, 96, 120 |

The summary of the leach under optimized conditions are shown in Table 13.52.

**Table 13.52 Results of the Leach under Optimized Conditions**

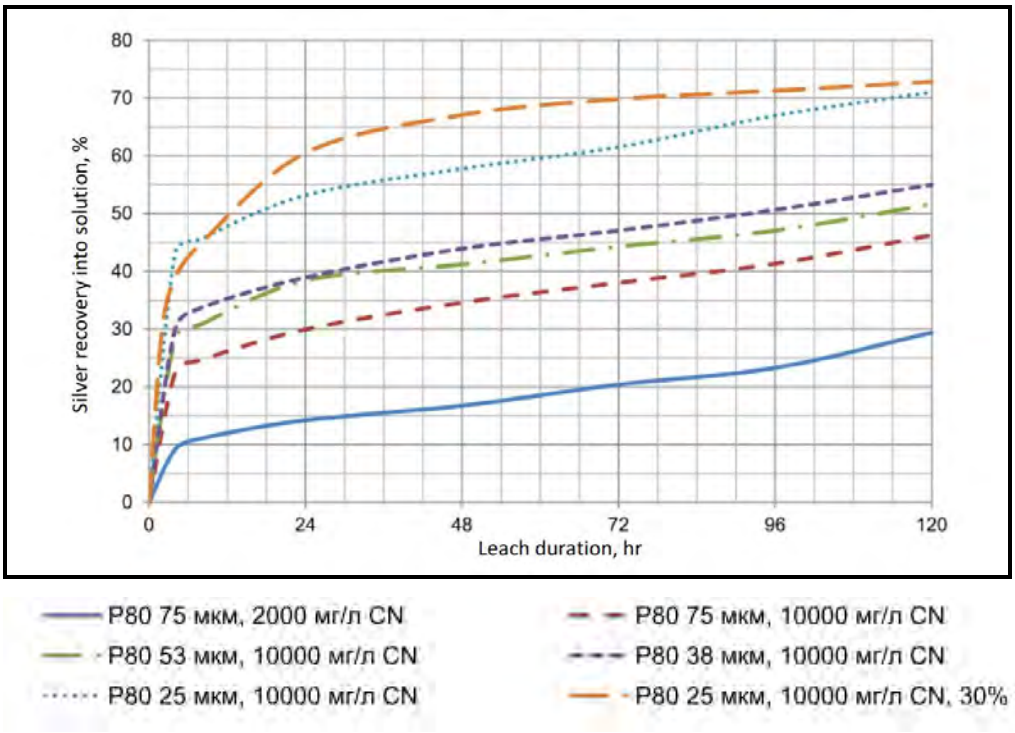
| Test Reference | Head Grade (Ag g/t) | Tails Grade (Ag g/t) | Dissolution (Ag %) |
|---|---|---|---|
| Optimised Conditions | 371 | 100.8 | 72.83 |

The reduction in leach pulp density from 40% solids to 30% solids resulted in a marginal increase of overall silver dissolution from 71 to 72.8%. However the overall leach kinetics significantly increased from this pulp density reduction (Figure 13.31).

### *Summary of the Leach Test Results*

The leach optimization program indicated that leach kinetics are extremely slow for the primary ore when the dissolution is increased beyond 120 hours (Figure 13.31).

**Figure 13.31 Leach Kinetics Curves**




As shown in Figure 13.31, the test with the lowest pulp density (30% solids), finer particle size distribution ($P_{80}$ = 25 µm), and higher cyanide concentration (10,000 mg/l) has shown that better kinetics, with approximate silver dissolution of 70%, can be attained within 72 hours of leach time.

It is also clear from the leach optimisation program that the overall silver dissolution significantly increased with the finer grind and higher cyanide concentration as shown Figure 13.32 and Figure 13.33.

**Figure 13.32 Variation of Leach Dissolution with Grind Size**

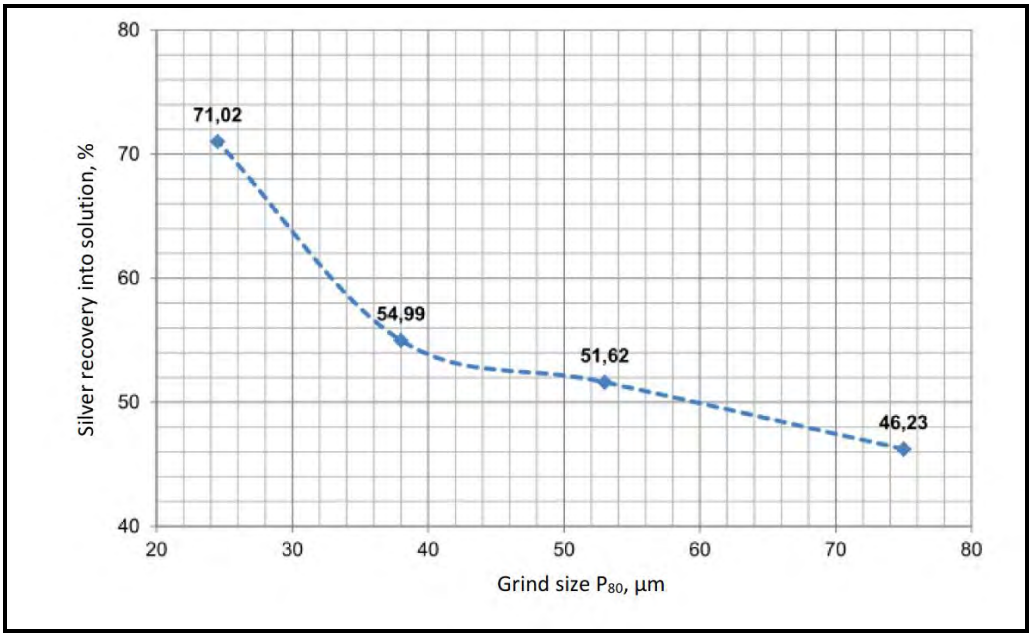
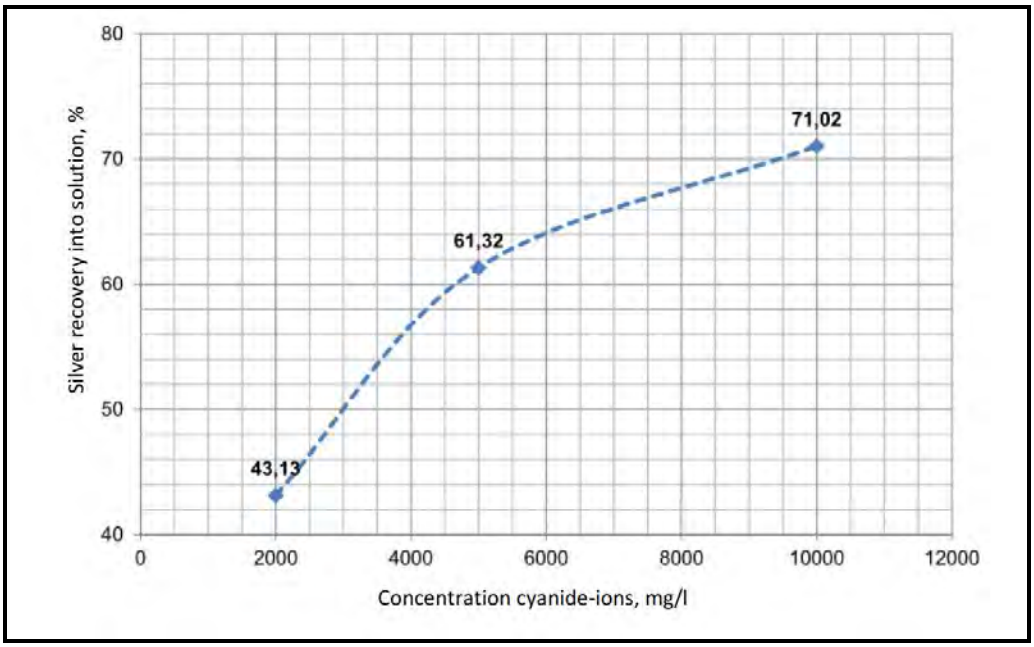



**Figure 13.33 Variation of Leach Dissolution with Cyanide Concentration**




### *Multiple Linear Regression Analysis*

Tetra Tech has undertaken a multiple linear regression (MLR) analysis of the primary ore leach test results in order to identify the most significant and least significant factors for silver dissolution. The summary of MLR analysis is shown in Table 13.53 and Table 13.54.

**Table 13.53 Summary of MLR Analysis**

| Ag Rec % | $X_1$ ($P_{80}$ µm) | $X_2$ (% Solids) | $X_3$ (CN Conc' mg/l) | $X_4$ (CN Cons' kg/t) | $X_5$ (CaO Cons' kg/t) |
|---|---|---|---|---|---|
| 29.38 | 75 | 40 | 2000 | 13.4 | 6 |
| 46.23 | 75 | 40 | 1000 | 37.8 | 6 |
| 51.62 | 53 | 40 | 1000 | 41.6 | 6.3 |
| 54.99 | 38 | 40 | 1000 | 43.7 | 6.2 |
| 43.13 | 25 | 40 | 2000 | 9.8 | 9.9 |
| 61.32 | 25 | 40 | 5000 | 21.7 | 10.6 |
| 71.02 | 25 | 40 | 10000 | 49.3 | 9.8 |
| 72.83 | 25 | 30 | 2000 | 58 | 14.1 |

**Table 13.54 MLR Parameters**

| $X_5$ | $X_4$ | $X_3$ | $X_2$ | $X_1$ | b |
|---|---|---|---|---|---|
| 4.7102 | 0.7371 | -0.0003 | 2.8802 | -0.0381 | -121.162 |

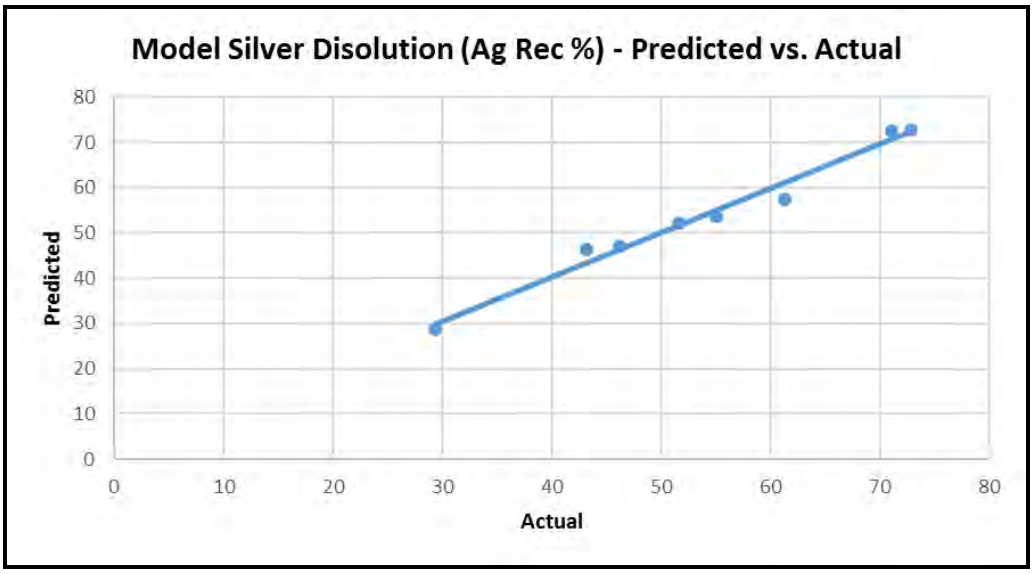
The MLR results were interpreted by expressing the constants in the form of a dissolution deviation equation.

$$Ag\ Rec\ \% = X_1.(P_{80}\ um) + X_2.(\%\ Solids) + X_3.(CN\ Conc') + X_4.(CN\ Cons') + X_5.(CaO\ Cons') + b$$

The dissolution deviation equation suggests that the silver dissolution is predominantly influenced by the lime consumption, followed by slurry density. However the bigger constant indicates that there are unknown parameters which has not been monitored during the test work that has a significant influence in the overall silver dissolution.

The dissolution deviation equation has been used to predict the silver dissolution in order to validate the MLR analysis and an excellent correlation has be observed between predicted and actual dissolutions (Figure 13.34).

**Figure 13.34 Validation of MLR Constants**




## 13.5.7 FLOTATION TEST WORK

The flotation test work included initial optimisation tests followed by an open cycle bulk flotation test in order to prepare a sample for intensive cyanidation tests. All of the flotation tests were conducted in a laboratory bench scale flotation cell (Figure 13.35).

**Figure 13.35 Laboratory Flotation Test**

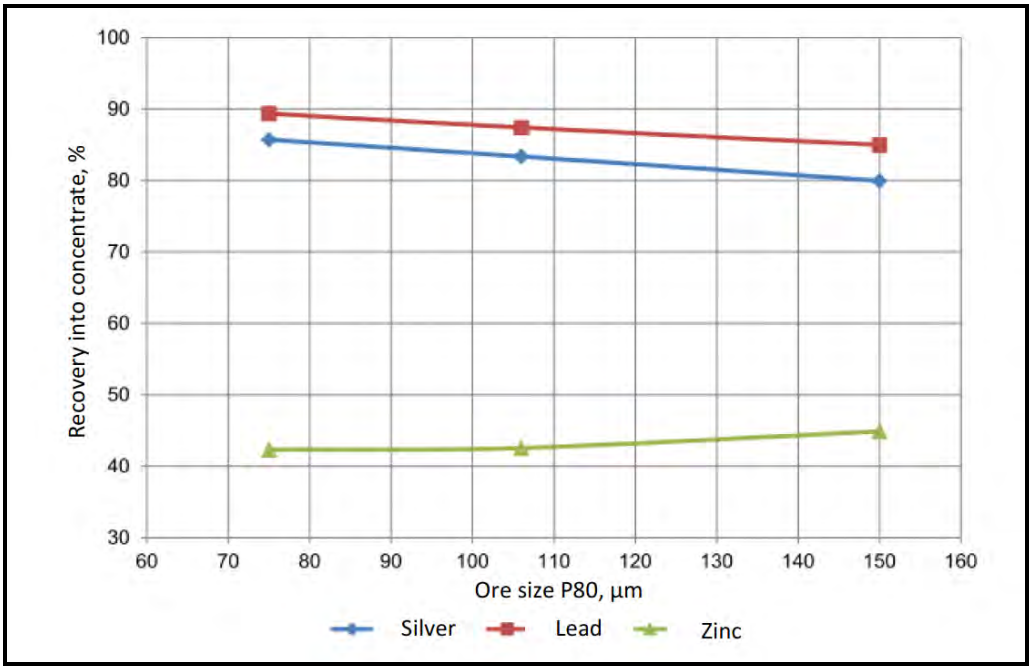
### *Flotation Optimization Tests*

Effect of grind and reagent scouting tests were conducted as the primary step in flotation in order to establish the optimal flotation conditions. A summary of the effect of these optimisation tests are shown in Table 13.55 and Figure 13.36 . Full details of the test conditions and detail results are shown in the Appendix A.

**Table 13.55 Effect of Grind Results**

| Grind Size ($P_{80}$-µm) | Product | Masspull (%) | Grade (Ag g/t) | Recovery (Ag %) | Grade (Pb %) | Recovery (Pb %) | Grade (Zn %) | Recovery (Zn %) |
|---|---|---|---|---|---|---|---|---|
| 150 | Concentrate | 11.35 | 2,667 | 79.94 | 22 | 84.97 | 14.4 | 44.88 |
| | Middlings scavenger | 18.2 | 307 | 14.76 | 1.85 | 11.47 | 5.81 | 29.05 |
| | Middlings control | 11.75 | 61.4 | 1.91 | 0.344 | 1.38 | 1.78 | 5.75 |
| | Flotation tails | 58.7 | 21.9 | 3.4 | 0.109 | 2.18 | 1.26 | 20.32 |
| | Head ore | 100 | 379 | 100 | 2.935 | 100 | 3.64 | 100 |
| 106 | Concentrate | 12.3 | 2,452 | 83.35 | 18.91 | 87.4 | 12.03 | 42.55 |
| | Middlings scavenger | 21.8 | 209 | 12.59 | 1.17 | 9.58 | 5.2 | 32.61 |
| | Middlings control | 14.55 | 36.6 | 1.47 | 0.237 | 1.3 | 1.7 | 7.11 |
| | Flotation tails | 51.35 | 18.2 | 2.58 | 0.089 | 1.72 | 1.2 | 17.72 |
| | Head ore | 100 | 362 | 100 | 2.66 | 100 | 3.48 | 100 |
| | Concentrate | 13.25 | 2,401 | 85.71 | 19.16 | 89.37 | 11.32 | 42.3 |
| 75 | Middlings scavenger | 24.2 | 166 | 10.82 | 0.94 | 8.01 | 5.17 | 35.3 |
| | Middlings control | 14.95 | 31.2 | 1.26 | 0.215 | 1.13 | 1.68 | 7.09 |
| | Flotation tails | 47.6 | 17.2 | 2.21 | 0.089 | 1.49 | 1.14 | 15.31 |
| | Head ore | 100 | 371 | 100 | 2.84 | 100 | 3.54 | 100 |

**Figure 13.36 Summary of Effect of Grind Test Results**



The results indicate that the $P_{80}$ = 75 µm grind have provided the highest silver (85.7%) and lead recoveries with lowest zinc recoveries. At this grind ($P_{80}$ = 75 µm) the concentrate silver grade and mass pull are expected at approximately 2,400 g/t and 13%, respectively.

The direct relationship between silver and lead recoveries and inverse relationship between silver and zinc recoveries could be interpreted as the primary silver minerals are mostly associated with galena rather than sphalerite.

### *Bulk Flotation Tests*

Bulk flotation tests were conducted at a grind of $P_{80}$ = 75 µm in order to prepare a feed sample for the intensive cyanidation tests.

The summary of the bulk flotation test results are shown in Table 13.56.

**Table 13.56 Bulk Flotation Results**

| Product | Masspull (%) | Grade (Ag g/t) | Recovery (Ag %) | Grade (Pb %) | Recovery (Pb %) | Grade (Zn %) | Recovery (Zn %) |
|---|---|---|---|---|---|---|---|
| concentrate | 14.84 | 2,333 | 93.59 | 19.69 | 96.03 | 11.59 | 44.7 |
| Tailings | 85.16 | 27.83 | 6.41 | 0.142 | 3.97 | 2.5 | 55.3 |
| Head ore | 100 | 370 | 100 | 3.04 | 100 | 3.85 | 100 |

The bulk flotation results confirm that approximately 93.6% of silver can be concentrated in to a polymetallic concentrate with approximately 15% masspull. The expected concentrate silver grade is 2,333 g/t.

### *Intensive Leach Tests*

The flotation concentrates were tested for intensive cyanidation using three different sets of conditions, as shown in Table 13.57.

**Table 13.57 Test Conditions for Intensive Cyanidation Tests**

| Parameter | Unit | Value | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Grinding Size $P_{80}$ | µm | 25 | | 15 |
| pH | - | 11.5 | | |
| Concentration Cyanide-ions | mg/L | 20,000 | 30,000 | |
| Concentration DO | mg/L | Around 8.4-8.8 | | |
| Pulp Aeration | - | Pure oxygen | | |
| Pulp Density | % solids | 25 | | |
| Leaching Duration | h | 144 | | |
| Solution Sampling | h (from start of test) | 2, 4, 8, 24, 48, 72, 96, 120, 144 | | |

The results of the intensive cyanidation tests are summarized in Table 13.58.

**Table 13.58 Intensive Cyanidation Results**

| Test Reference | Grind Size ($P_{80}$ µm) | Cyanide Concentration (mg/l) | Head Grade (g/t) | Tails Grade (g/t) | Dissolution (%) |
|---|---|---|---|---|---|
| Test 1 | 25 | 20,000 | 2333 | 1940 | 16.85 |
| Test 2 | | 30,000 | | 1711 | 26.66 |
| Test 3 | 15 | | | 1776 | 23.87 |

It appears that the intensive cyanidation of flotation concentrate resulted in very poor dissolutions. The best silver dissolution (26.7%) was obtained at a $P_{80}$ = 25 µm grind and a cyanide concentration of 30,000 ppm. This is a clear indication that the concentrate is not amenable to cyanidation at the tested grinds and selected conditions suggest that silver mineral might be refractory. Based on this test, it can be concluded that the intensive cyanidation of flotation concentrates is not a viable process option for the primary ore.

## 13.6 Process Selection and Flowsheet Development

The completed test work indicates that the oxide and primary ores are mineralogically similar but their amenability to various metallurgical processes have significant differences. It is understood that both oxide ore and primary ore can be separated at the mining stage and processed in separate campaigns through the processing plant. In this context, two different process approaches are proposed to economically extract the silver.

### 13.6.1 Oxide Ore Processing

The oxide ore from the Mangazeisky deposit is free milling, amenable to gravity concentration and cyanidation.

The comminution test work indicates that the oxide ore is generally considered as moderately hard. Based on the test work a comminution circuit that contains two stage crushing followed by ball mill grinding in order to produce a feed with $P_{80}$ = 75 µm is recommended.

Gravity concentration followed with intensive leaching of the concentrates and agitated tank leach of the gravity tails has shown to be the most economical approach to get maximum silver dissolution. Hence, a gravity circuit and an intensive leach circuit are recommended for the oxide ore processing.

The leach optimisation study indicates a 72-hour leach retention time along with a pH of 11.5 and cyanide concentration of 2 g/l would provide better economic returns on gravity tails. Thus, agitated tank leaching with a 72-hour retention time is recommended.

The direct electrowinning test work indicates that this technology has significant advantages for this type of ore. Therefore direct electrowinning is recommended for the silver extraction method from cyanide leach solutions.

In summary, the conceptual process flowsheet reported in the PEA has been validated with some modifications in order to reduce costs and maximise the silvery recovery from the oxide ore.

### 13.6.2 Primary Ore Processing

It is understood that the primary ore only constitutes a minor proportion (approximately 10%) of the feasibility study ore reserves and mining schedule. Thus, utilizing the oxide ore process plant with required modifications is proposed as an approach for the feasibility study.

The comminution test work indicates that the primary ore is generally considered as extremely hard. The leach optimization work indicated that a finer grind at $P_{80}$ = 25 µm is required to achieve reasonable silver dissolution. The increased hardness and reduced grind size require more grinding energy. However the same flowsheet used for the oxide ore (two-stage crushing followed by ball mill grinding) can be utilized for the primary ore. Hence, Tetra Tech recommends the same comminution circuit but an increased milling capacity.

The test work indicates that the primary ore is amenable to flotation; however, the intensive leaching of flotation concentrates have resulted in very poor silver dissolutions. In addition, it must be recognized that the site location is very remote with challenging environmental and logistical problems. This works against the flotation process which has demanding requirements, for example the supply and availability of reagents as well as the production and transportation of the concentrate to a suitable smelter. In this context flotation is not recommended as a process flowsheet option for processing the primary ore.

The test work also indicates that the primary ore is amenable to direct cyanidation at finer grinds and higher cyanide concentrations with extremely slow leach kinetics.

The leach optimisation study indicates a 120 hour leach retention time along with a pH of 11.5 and cyanide concentration of 10 g/l would provide maximum silver dissolution. Thus, increasing the number of tanks in order to achieve a leach retention time of 120 hours is recommended.

In terms of electrowinning, utilising the same direct electrowinning circuit is recommended.

In summary, the utilising the oxide ore flow sheet with minimal modifications in order to managed the ore hardness, finer grind and longer leach time requirements is recommended for the processing of the primary ore.

## 13.7 Metallurgical Recovery

Metallurgical recovery for the oxide ore and the primary ore estimated based on the reported test work and proposed plant design.

### 13.7.1 Oxide Ore Recovery

The oxide ore recovery is estimated based on a gravity and leach flowsheet (Figure 13.16) incorporating the variability leach test work. It is important to note that the variability leach test work was conducted on the ROM ore as a result of lack of sample availability. The variability leach result has been pro-rated, as shown in Table 13.59, in order to be consistent with the plant design conditions.

**Table 13.59 Pro-rating of Variability Leach Results for Plant Design Conditions**

| Description | Dissolution (%) | Conditions |
|---|---|---|
| ROM Leach Dissolution (SGS) | 82.1 | $P_{80}$ = 75 µm, pH = 11.5, CN = 2,000 ppm, 40% Solids, 72 h |
| Gravity Tails Leach (SGS) | 88.2 | $P_{80}$ = 75 µm, pH = 10.5, CN = 2,000 ppm, 40% Solids, 72 h |
| Dissolution Adjustment Factor (TT) | 6.1 | N/A |
| Variability Leach Dissolution* (oxides – ROM, TOMS) | 79.7 | $P_{80}$ = 75 µm, pH = 11.5, CN = 2,000 ppm, 40% Solids, 72 h |
| Adjusted Variability Leach Dissolution (oxides Gravity Tails, TT) | 85.8 | N/A |

Notes: *mean value of all leach tests on oxide samples
SGS – Test completed in SGS Vostok; TOMS – Test Completed in TOMS;
TT – Tetra Tech calculation by pro-rating; N/A – Not Applicable

The pro-rated variability leach dissolution for gravity tails leach has been used along with the gravity silver recovery and intensive leach dissolution in order to calculate the overall leach recovery for oxide ore. The summary of overall recovery calculation is shown in Table 13.60.

**Table 13.60 Overall Recovery Calculation for Oxides**

| Gravity Concentrates | Amount |
|---|---|
| Silver Recovery to Gravity Concentrate (%) | 7.9 |
| Silver Dissolution at Intensive Cyanidation (%) | 98.0 |
| Silver Reported to Intensive Leach Solution (%) | 7.7 |
| **Gravity Tails** | |
| Silver Recovery to Gravity Tails (%) | 92.1 |
| Silver Dissolution of Tank Leach | 85.8 |
| Silver Recovery to Standard Leach Solution (%) | 79.0 |
| **Overall Recovery** | |
| Overall Silver Dissolution to Solution (%) | 86.7 |
| Electrowinning Efficiency (%) | 99.0 |
| Dissolved Silver Losses (%) | 1.0 |
| Overall Silver Recovery (%) | 85.0 |

Based on the data presented in Table 13.60, the overall silver recovery for oxide ore is estimated as 85.0%.

### 13.7.2 PRIMARY ORE RECOVERY

The primary ore recovery is estimated based on the leach test work completed in TOMS.

Based on a leach dissolution 71.02% (120-hour leach retention time) the recovery is calculated as 69.6% assuming 99% electrowinning efficiency and 1% dissolved silver losses.

# 14.0 MINERAL RESOURCE ESTIMATES

## 14.1 SUMMARY

Tetra Tech completed a new Mineral Resource estimate for the Vertikalny deposits, with an effective date of 8th July 2016. The most recent data included in the estimate was received on 1st July 2016. Mr. Robert Davies, BSc, EurGeol, CGeol, an independent QP as defined by NI 43-101, estimated the Mineral Resources.

This section also presents a restatement of the Mineral Resource for the Nizhny Endybal deposit, situated approximately 2.5 km east of the Vertikalny deposit, and the Mangazeisky North deposits located 7 km to the north of Vertikalny.

The effective date of the Nizhny Endybal Mineral Resource is 11 September 2012. Mr. P. Gribble, FIMMM, C.Eng, former Senior Geologist at Tetra Tech is the independent QP who originally prepared the Nizhny Endybal Mineral Resource. Mr. Davies has reviewed and verified the Nizhny Endybal Mineral Resource as current.

The effective date of the Mangazeisky North Resource is 31st March 2016. The effective date of the Mangazeisky South Resource is 3rd June 2015. The Mineral Resources have been estimated by Mr. Robert Davies.

Further details of the Nizhny Endybal and Mangazeisky North Mineral Resource estimates are publically available in technical reports prepared by Tetra Tech and filed under the Silver Bear profile on the Canadian Security Administrators' SEDAR, in 2012, 2015 and 2016.

### 14.1.1 SUMMARY OF ESTIMATION TECHNIQUES

Tetra Tech created wireframe models using Leapfrog Geo (Version 3.1). Wireframes were created to represent lithologies, oxidation state and mineralised bodies. Wireframes were developed for strongly mineralised core zones and where present less strongly mineralised wall rock alteration (as described in Section 14.2.1). Variography, block modelling and resource estimation were completed in GEOVIA Surpac software (version 6.7).

The silver grades for the Vertikalny Central and Northwest zones were estimated using OK interpolation methodology. Density for the Central Zone was estimated using $IDW^2$, while density was assigned for the Northwest Zone.

Statistical and grade continuity analyses were completed in order to characterise the mineralisation, and were subsequently used to develop grade interpolation parameters. Grade estimation was completed using OK. The search ellipsoid dimensions and orientations were chosen to reflect the continuity revealed by geostatistical studies. Block size, discretisation, search size, and sample numbers were optimised using QKNA.

Tetra Tech adopted the definition of Mineral Resources as outlined within the CIM Definition Standards on Mineral Resources and Mineral Reserves (CIM 2014) in order to classify the resources.

In order to demonstrate that the deposit has reasonable prospects for economic extraction, a cut-off grade of 200 g/t silver has been applied for resources contained within an open pit shell at Vertikalny Central or within 80 m of surface at Vertikalny Northwest. A 350 g/t silver cut-off has been applied for the underground resource, based upon the following assumptions:

- silver price of $17.00/troy oz
- mining cost $2.53/t open pit and $70.00/t underground
- processing cost of US$52.00/t
- general and administration costs of US$40.60/t.

At Vertikalny Central, a pit shell wireframe was used to constrain the open pit resource in order to demonstrate that the resource has reasonable prospects for economic extraction. The pit shell was developed using the following assumptions:

- silver price of $19.00/troy oz
- mining recovery 95%
- waste dilution 30%
- mining cost of US$2.53/t
- processing cost of US $52.00/t
- general and administration costs of US$40.60/t
- royalty of 6.5%
- overall silver recovery of 88%.

In order to demonstrate that the deposit has reasonable prospects for economic extraction, a cut-off grade of 150 g/t was applied for the Mangazeisky North and Nizhny Endybal deposits, based upon the following assumptions:

- forecasted silver price of $17.00/troy oz open pit mining cost of $3.16/t
- processing cost of $50/t
- general and administrative costs of $12.50/t
- transport costs, from pit to process plant, of $3.60/t
- overall silver recovery of 80%.

## 14.2 DATABASE

Silver Bear provided Tetra Tech with its exploration database, in the form of excel spreadsheet containing the following tabs:

- collar

- survey
- assay
- density
- geotechnical
- lithology.

The database include information on trenches and drillholes sampled during the period from 2007 through to the summer 2015.

The resource update for Vertikalny Central benefited from an additional 15 diamond holes drilled in 2014, but assayed in 2015, 6 diamond holes drilled and assayed in 2015 and 21 trenches that were excavated in 2014 but assayed in 2015. An additional eight holes were drilled on the Vertikalny Northwest deposit in 2015.

## 14.3 GEOLOGICAL INTERPRETATION

The Vertikalny deposit is interpreted to be a breccia and vein hosted, epithermal silver deposit, hosted within a relatively vertical, northwest-southeast trending fault zone. The mineralisation is associated with vertical dykes of dacitic composition. Based on the surrounding deposits and the host rock, it is interpreted that the Vertikalny deposit formed through the re-mobilisation of strata-bound silver-lead-zinc mineralisation, into breccia and vein-hosted high-grade deposits of variably oxidized manganosiderite-sphalerite-galena mineralisation, with silver sulphosalts and native silver.

It is interpreted that one of the controls on mineralisation is the interaction between oblique subordinate faults, with the main mineralised structure. Whilst the main structure at Vertikalny Central is mineralised along its entire strike length, the highest grade zones appear to be coincident with the intersection between the mineralised body and oblique fault plane.

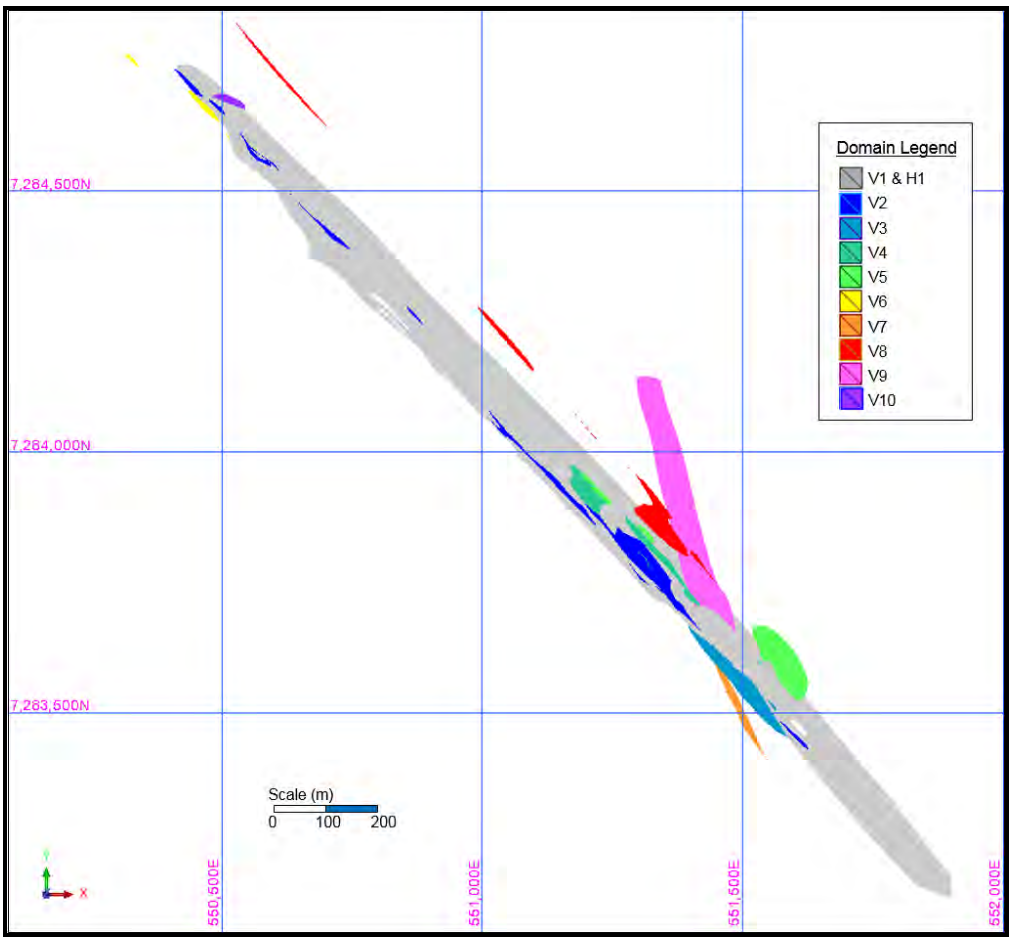
### 14.3.1 STRONGLY MINERALISED ZONE

During the logging of the 2013-2015 seasons, it was noted that within the brecciated/mineralised zone there existed a subset of more strongly mineralised, and hence higher-grade mineralisation. These subset intervals were compared to the assay results and were shown to have a good correlation with the highest-grade intervals in each logged hole. These observations were applied to drillholes and trenches from earlier campaigns by using silver grades to define the strongly mineralised core within the mineralised zone. Less strongly mineralised material was grouped into a wall rock alteration model. The strongly mineralised domain was named V1, with the alteration halo named H1.

### 14.3.2 SUBORDINATE PARALLEL AND OBLIQUE VEINS

At Vertikalny Central a series of subordinate parallel and oblique veins have been modelled, in addition to the main V1/H1 domain. The veins have limited continuity, but do contain some pockets of strong silver mineralisation, Figure 14.1.

**Figure 14.1 Mineralised Domains at Vertikalny Central**




Source: Tetra Tech

### 14.3.3 WIREFRAME MODELLING

Implicit wireframe models were generated in Leapfrog Geo Version 3.1. The models were created based upon interval selections that referenced both the silver and lead grades, lithological descriptions and structural interpretation. The lead grades provided an indication of the style of mineralisation and abundance of galena in the vein.

The models were created as a series of tightly constrained sub-vertical veins that could pinch and swell according to the informing drillhole data, Figure 14.2 and Figure 14.3.

**Figure 14.2 Plan and Cross Section through Vertikalny Central Wireframe Models**

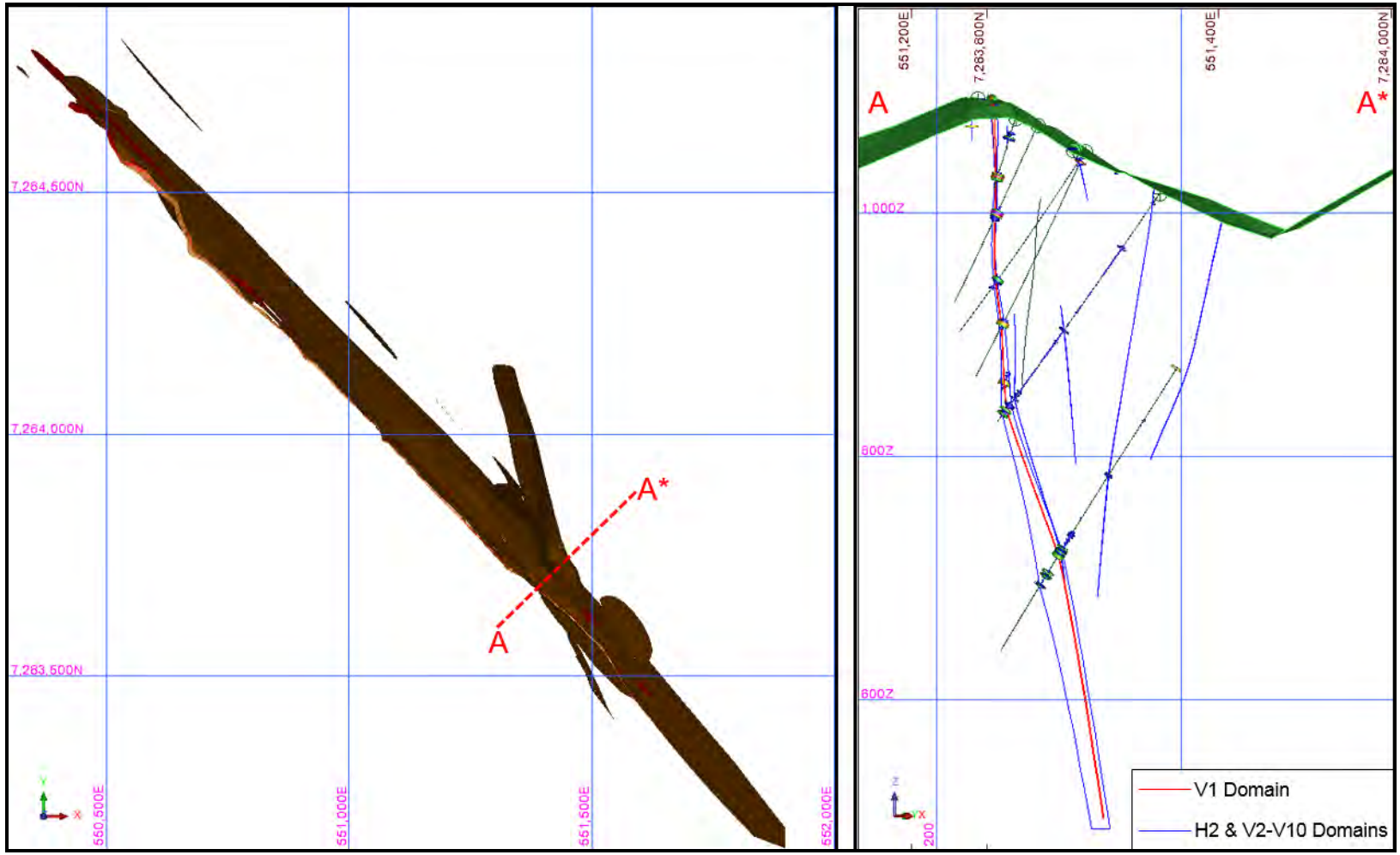
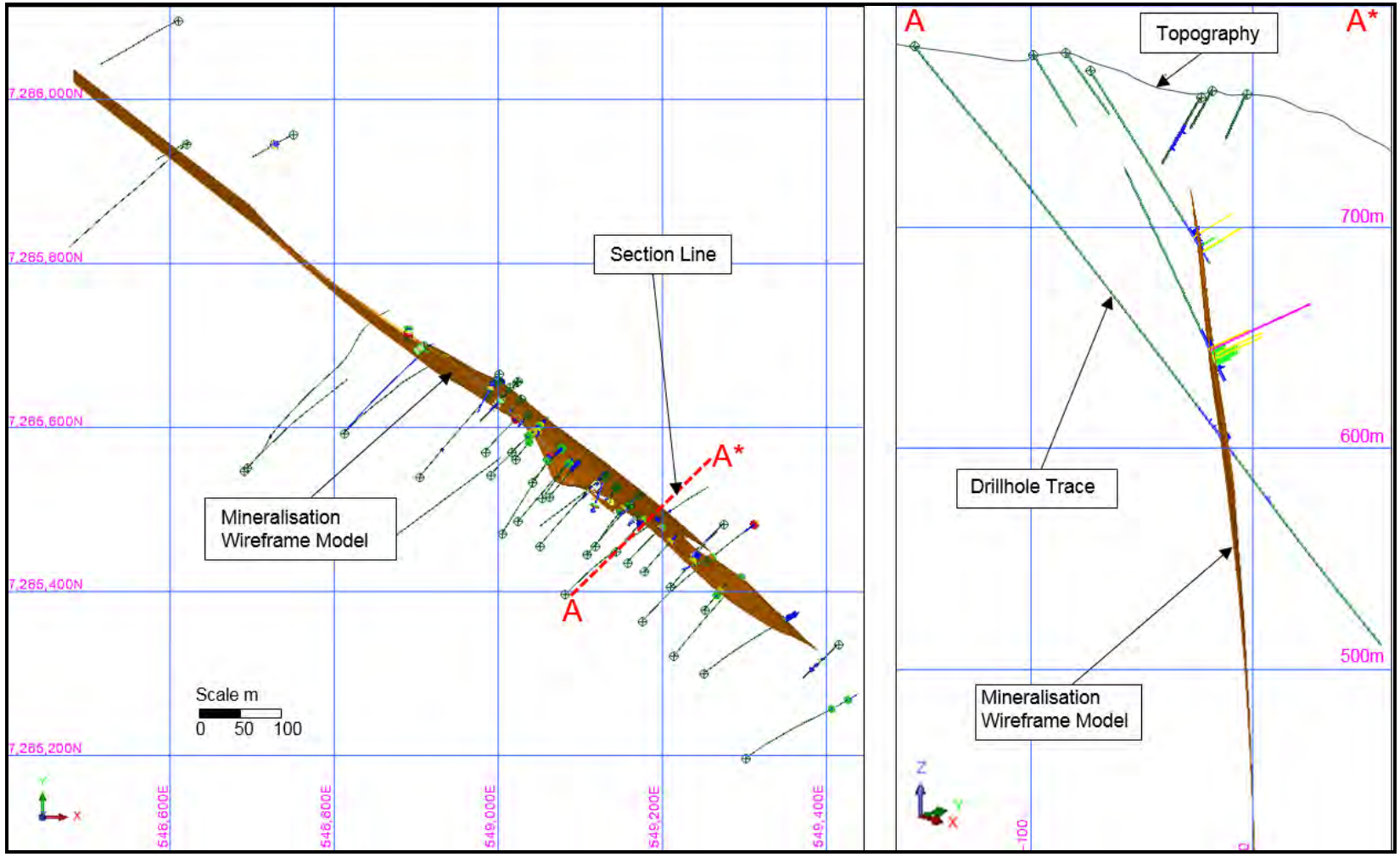


**Figure 14.3 Plan and Cross Section through Vertikalny Northwest Wireframe Models**



## 14.4 EXPLORATORY DATA ANALYSIS/DOMAINING

The main zone at Vertikalny central has been subdivided into two domains, a high-grade core (domain V1) and a low-grade halo (domain H1), based upon exploratory data analysis (EDA) described herein. The remaining domains at Vertikalny Central include V2, V3, V4, V5, V6, V7, V8, V9 and V10, which represent the subordinate parallel and oblique veins. There is a single domain at Vertiklany Northwest, referred to as VNW1. The EDA indicated that there are differences in mineralogy encountered in the mineralisation zones, which control the different grade populations.

The subordinate parallel/ oblique veins and the Vertikalny Northwest area do not have sufficient sample numbers to allow division into sub-domains.

Various statistical analyses of the data were performed, and are documented in this section.

### 14.4.1 RAW DRILLHOLE STATISTICS

Tetra Tech received a total of 13,879 silver assay results from a series of drilling and trenching campaigns between 2007 and 2015.

Analysis for base metals, including copper, lead and zinc was also completed for 8,529 samples. The base metals have been estimated into the block model for information, but are not currently included within the mineral resource due to them not having reasonable prospects for economic extraction, as required for compliant disclosure.

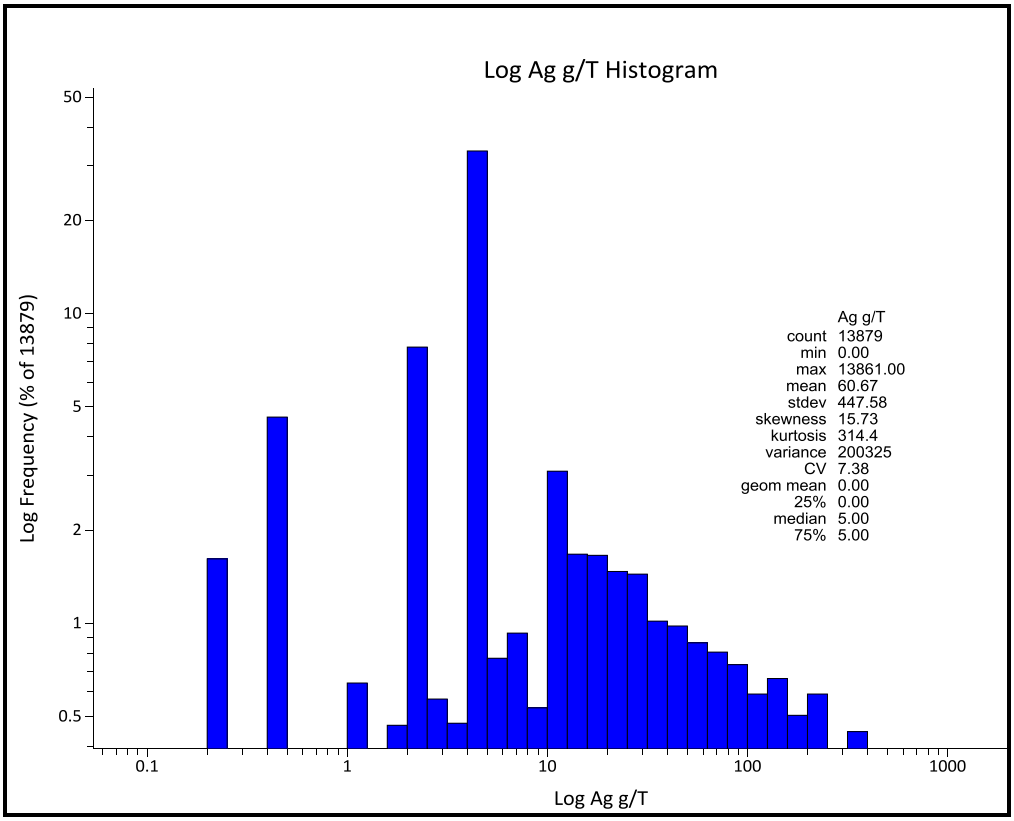
Table 14.1 presents the statistics for all raw silver and density data.

**Table 14.1 Raw Drillhole Statistics**

| Field | Ag Grade (g/t) | Density (t/m³) |
|---|---|---|
| No. of Samples | 13,879 | 393 |
| Minimum | 0 | 2.11 |
| Maximum | 13,861 | 6.23 |
| Range | 13,861 | 4.12 |
| Mean | 61 | 3.13 |
| Variance | 200,325 | 0.39 |
| Standard Deviation | 448 | 0.62 |
| Coefficient of Variation | 7 | 0.20 |

Statistical analysis of raw samples presents multiple grade populations (Figure 14.4). For robust grade interpolation the populations need to be differentiated and estimated independently.

**Figure 14.4 Log Histogram of all Raw Samples**




A series of domains have been identified based upon exploratory data analysis. The domains are described in Table 14.2.

**Table 14.2 Summary of Mineralisation Domains**

| Domain Name | Area | Description |
|---|---|---|
| V1 | Vertikalny Central | Sub-vertical persistent strongly mineralised vein at Verticalny central. Constitutes majority of the resource. |
| H1 | Vertikalny Central | Weakly mineralised alteration halo surrounding V1 |
| V2-V10 | Vertikalny Central | Subordinate parallel and oblique veins. Generally small narrow veins with poor continuity. |
| VNW | Vertikalny Northwest | Sub-vertical vein with strong mineralisation in places. Main structure at Vertikalny northwest. |

The wireframe models presented in Section 14.3.3, successfully differentiate the high-grade, low-grade, and waste populations. Statistics for the Vertikalny domains are presented in the box and whisker plot in Figure 14.5 and descriptive statistics in Table 14.3.

**Figure 14.5 Box and Whisker Plot of Selected Raw Samples**

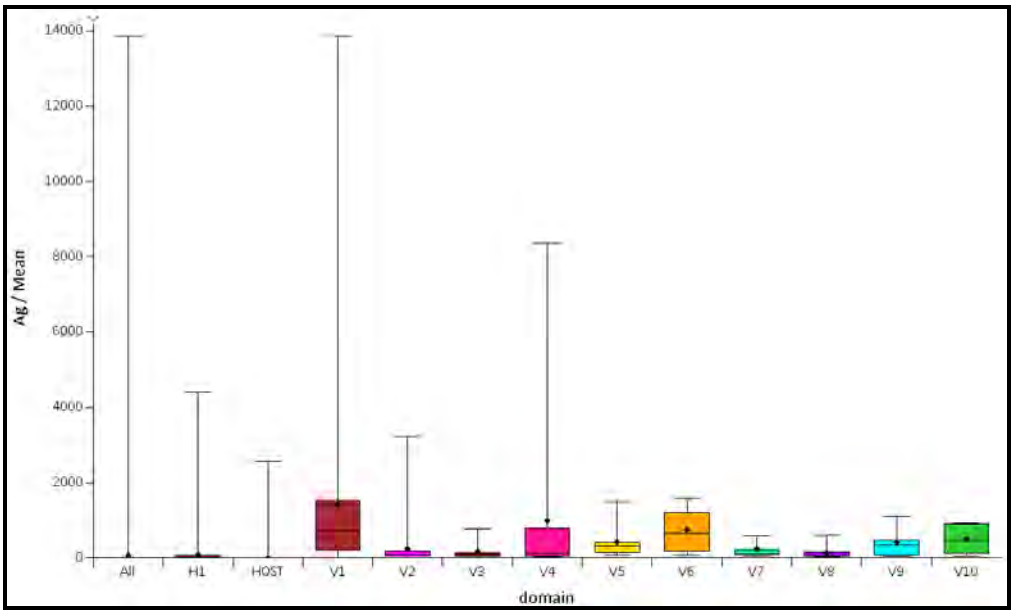



**Table 14.3 Descriptive Statistics for Selected Raw Samples**

| Domain | Count | Minimum | Maximum | Mean | Std Dev | CV | Skewness | Kurtosis | Geom Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|
| HOST | 11,455 | 0 | 2,578 | 8 | 56 | 7.3 | 24.0 | 747.5 | - | 2.5 |
| H1 | 1,447 | 0.25 | 4,407 | 76 | 185 | 2.5 | 12.3 | 240.0 | 28.2 | 24.6 |
| V1 | 413 | 6.8 | 13,861 | 1,413 | 2,076 | 1.5 | 2.9 | 9.4 | 536.5 | 722.0 |
| V10 | 5 | 61 | 929 | 503 | 413 | 0.8 | 0.1 | -4.6 | 318.1 | 485.0 |
| V2 | 55 | 5 | 3,229 | 246 | 541 | 2.2 | 4.5 | 21.2 | 77.6 | 76.8 |
| V3 | 8 | 7.1 | 770 | 180 | 246 | 1.4 | 3.0 | 8.6 | 79.0 | 134.2 |
| V4 | 14 | 32.5 | 8,369 | 1,001 | 2,199 | 2.2 | 3.7 | 13.5 | 221.7 | 113.5 |
| V5 | 7 | 88.36 | 1,503 | 432 | 491 | 1.1 | 2.8 | 7.3 | 282.3 | 324.5 |
| V6 | 4 | 76.2 | 1,590 | 747 | 718 | 1.0 | 0.6 | -6.3 | 417.9 | 660.5 |
| V7 | 5 | 59 | 589 | 243 | 208 | 0.9 | 2.1 | 4.0 | 181.5 | 218.0 |
| V8 | 9 | 26 | 621 | 140 | 196 | 1.4 | 2.7 | 6.7 | 72.8 | 45.0 |
| V9 | 9 | 53.6 | 1,114 | 410 | 373 | 0.9 | 1.3 | 0.2 | 262.1 | 349.0 |
| VNW | 102 | 5 | 4,030 | 369 | 612 | 1.7 | 3.6 | 15.7 | 154.7 | 156.4 |

The differentiated datasets approximate single log normal populations are shown in Figure 14.6, Figure 14.7, Figure 14.8 and Figure 14.9.

**Figure 14.6 Log Histogram of Selected Raw Samples from Domain V1**

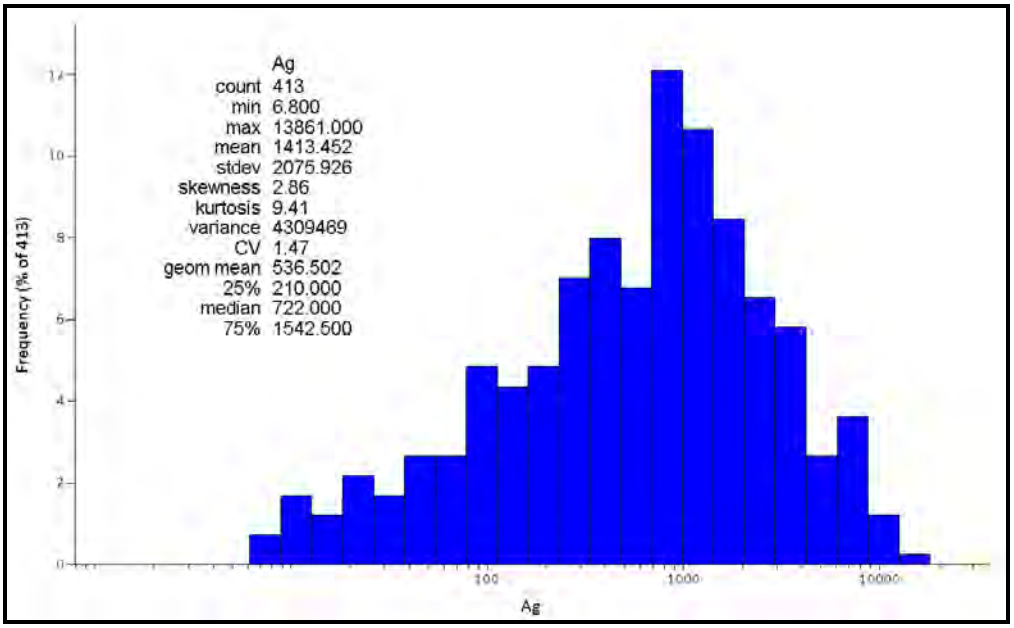
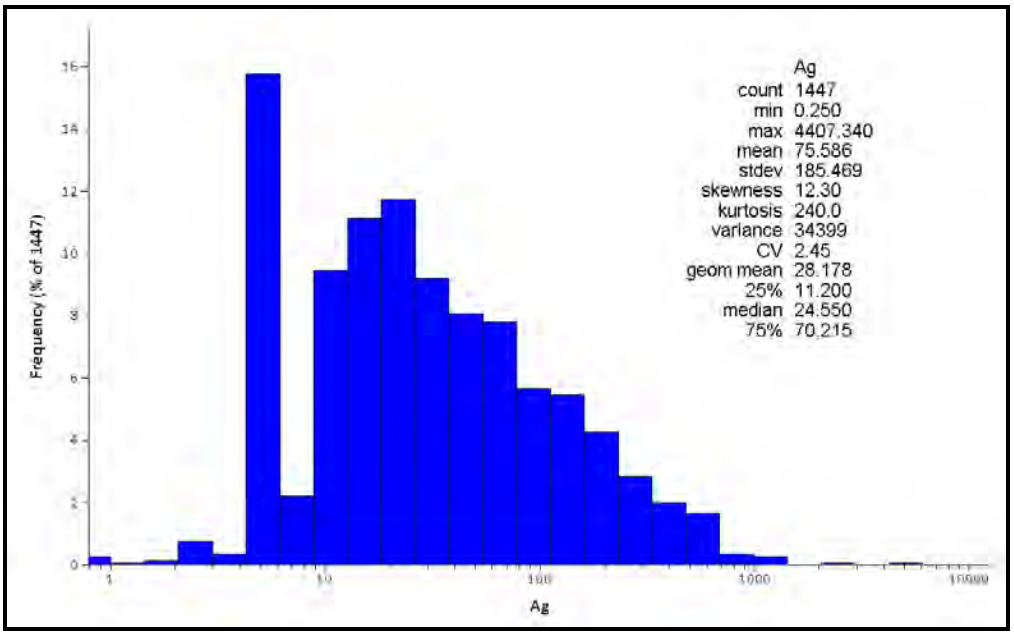



**Figure 14.7 Log Histogram of Selected Raw Samples from Domain H1**




Notes: For the majority of the samples the analytical detection limit is 5 g/t, this causes a spike in the histogram at this grade.

**Figure 14.8 Log Histogram of Selected Raw Samples from Domains V2-V10**

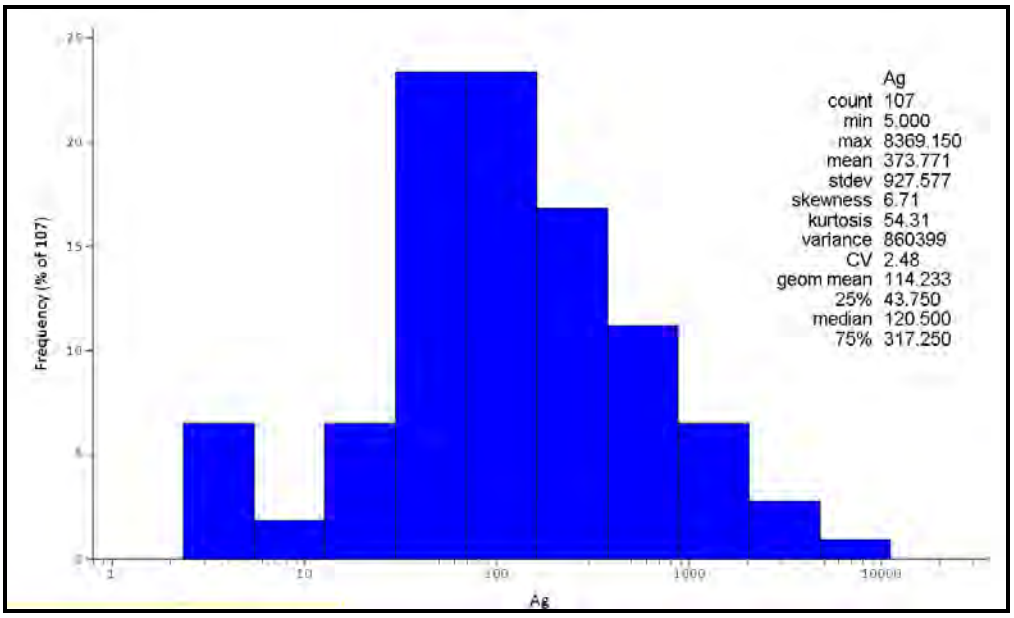
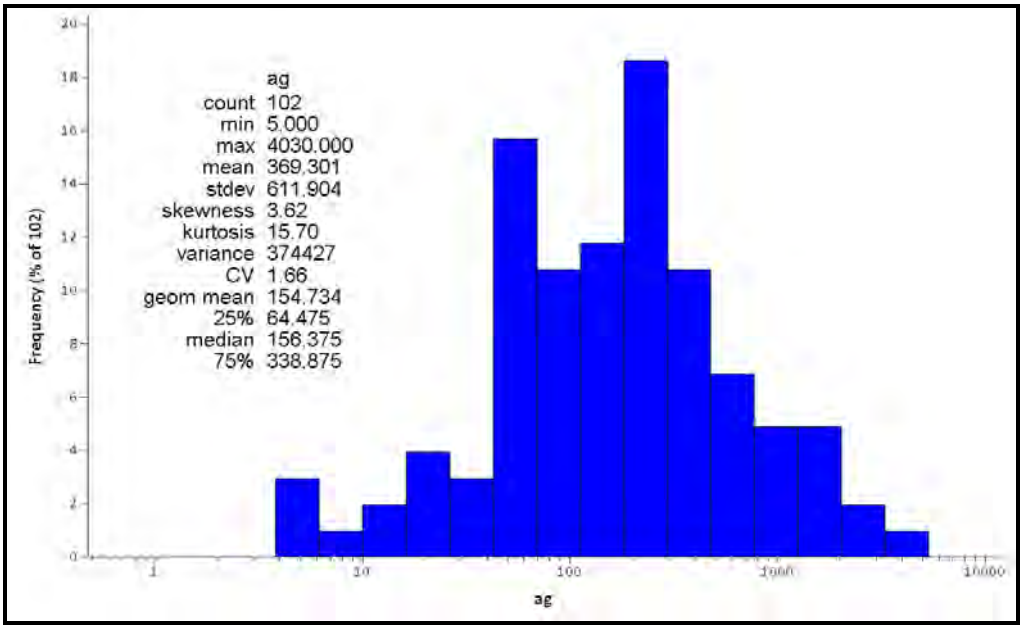


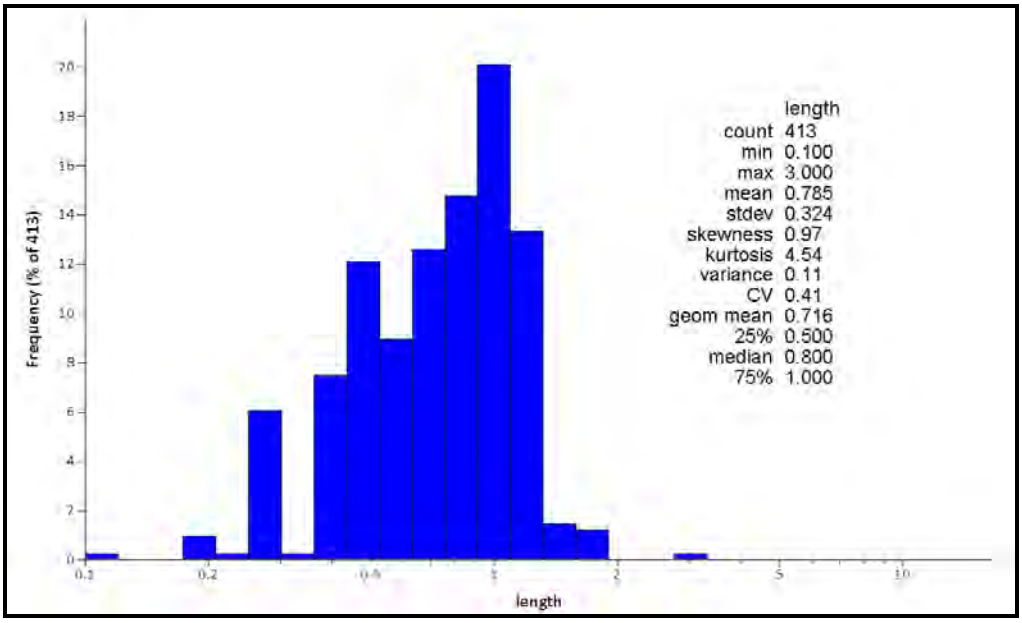

**Figure 14.9 Log Histogram of Selected Raw Samples from Domains VNW**




## 14.4.2 Sample Length and Compositing

Statistics on the sample lengths were analysed using histograms (Figure 14.10), and a length of 0.7 m was chosen as it is close to the mean and geometric mean. Compositing was completed in Surpac using a 0.7 m best fit routine, applying hard domain boundaries.

**Figure 14.10 Length Histogram for Selected Raw Samples with V1 Domain**




The compositing routines have been effective in preserving the grade distribution (Figure 14.10). However, the process has reduced the mean silver grade by 11% from 758 to 672 g/t. The reduction in grade is due to the presence of a number of very high-grade samples that have a length of less than 1 m (Figure 14.11). When the high-grade short samples are combined with lower-grade neighbouring samples to create a length weighted average grade over a standard 1-m length, the result is a small overall reduction in silver grade (Table 14.4).

**Figure 14.11 Sample Length Plotted Against Silver Grade**

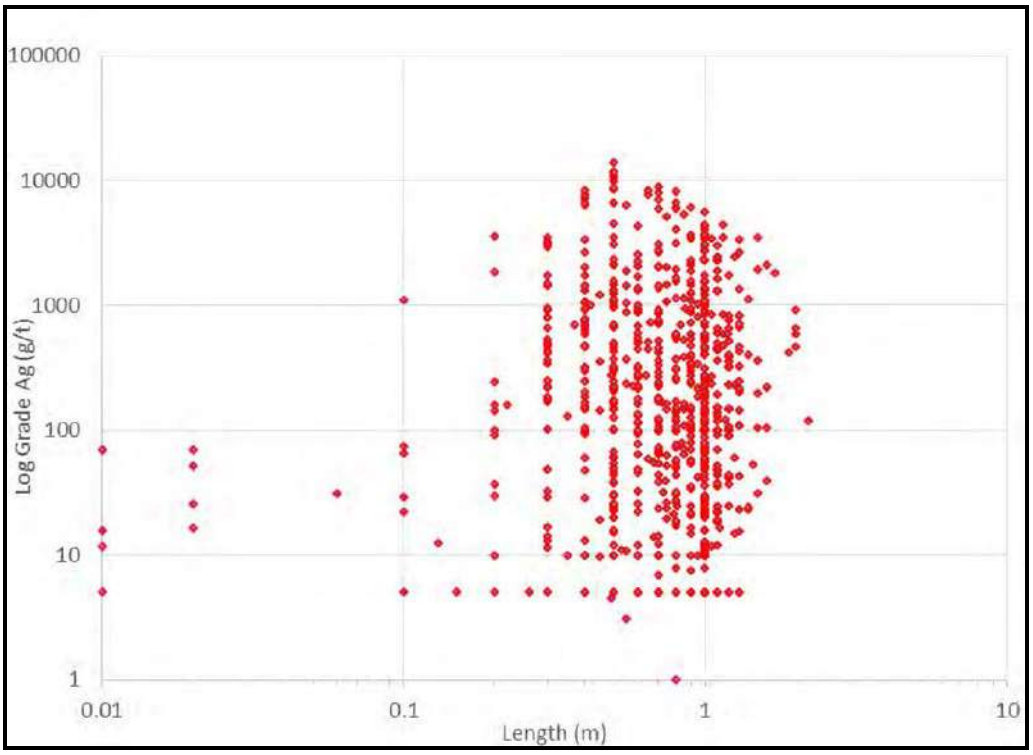


**Figure 14.12 Log Histogram of Silver Grades from Selected Raw Samples and 0.7 m Composites for Vertikalny Central Domains**

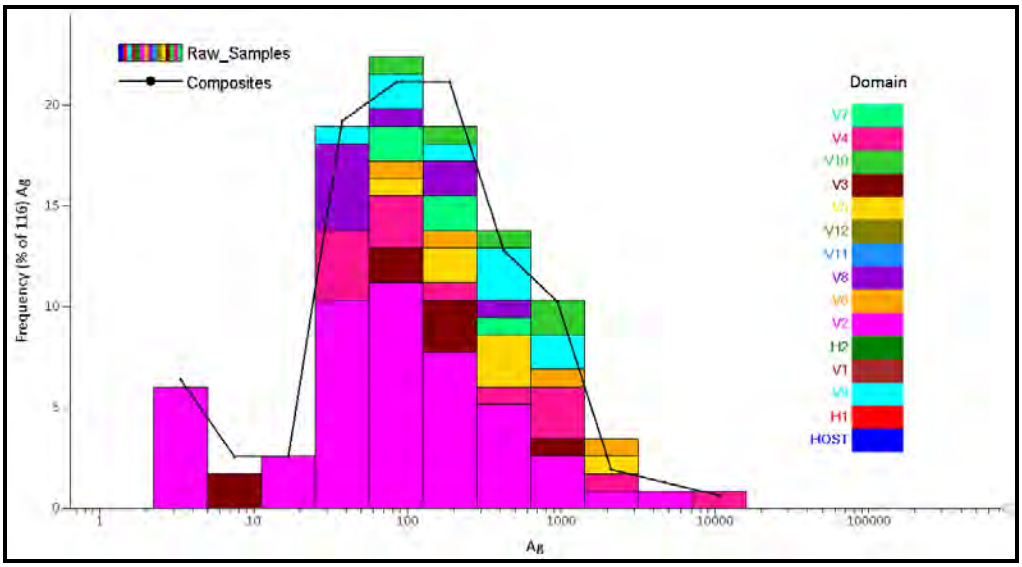


**Table 14.4 Table Statistics of Selected Raw Samples and 0.7 m Composites**

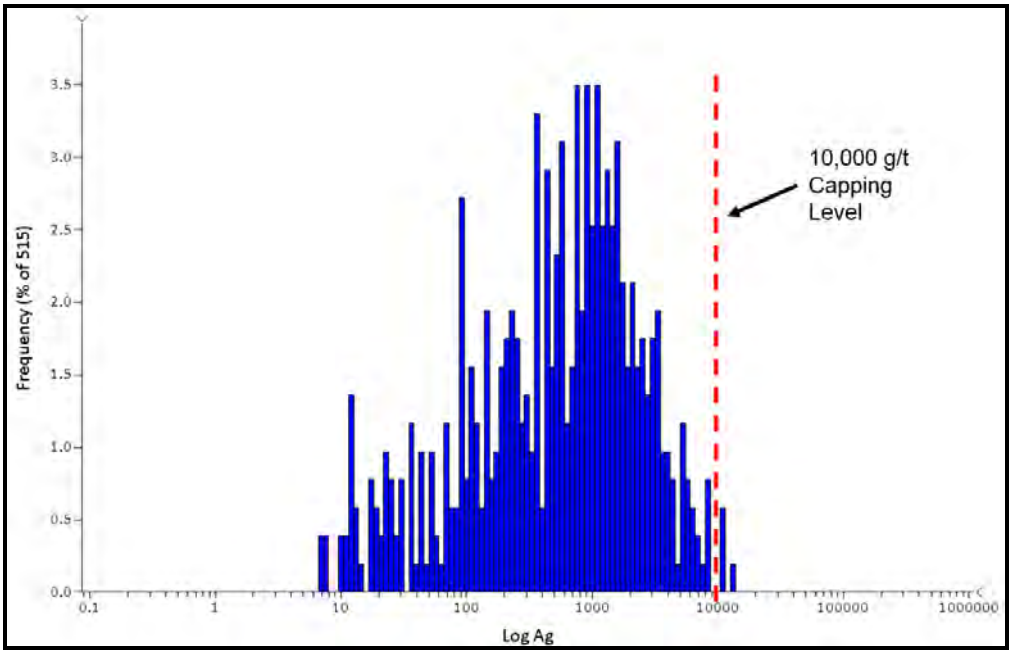
| Data | Domain | Count | Min | Max | Mean | Std Dev | CV | Skewness | Kurtosis | Geom Mean |
|---|---|---|---|---|---|---|---|---|---|---|
| Raw | H1 | 1447 | 0.25 | 4,407 | 76 | 185 | 2.45 | 12.30 | 240.00 | 28.18 |
| Cmps | H1 | 1770 | 0.25 | 4,393 | 72 | 177 | 2.44 | 13.19 | 262.50 | 30.23 |
| Raw | V1 | 413 | 6.8 | 13,861 | 1,413 | 2,076 | 1.47 | 2.86 | 9.41 | 536.50 |
| Cmps | V1 | 499 | 11.5 | 13,054 | 1,256 | 1,727 | 1.38 | 3.02 | 11.94 | 533.77 |
| Raw | V10 | 5 | 61 | 929 | 503 | 413 | 0.82 | 0.05 | -4.58 | 318.11 |
| Cmps | V10 | 5 | 61 | 929 | 503 | 413 | 0.82 | 0.05 | -4.58 | 318.11 |
| Raw | V2 | 55 | 5 | 3,229 | 246 | 541 | 2.20 | 4.45 | 21.18 | 77.64 |
| Cmps | V2 | 75 | 5 | 3,229 | 238 | 581 | 2.44 | 4.49 | 20.30 | 70.00 |
| Raw | V3 | 8 | 7.1 | 770 | 180 | 246 | 1.36 | 3.02 | 8.59 | 78.95 |
| Cmps | V3 | 12 | 7.1 | 770 | 171 | 226 | 1.32 | 2.37 | 5.17 | 65.11 |
| Raw | V4 | 14 | 32.5 | 8,369 | 1,001 | 2,199 | 2.20 | 3.72 | 13.47 | 221.70 |
| Cmps | V4 | 18 | 32.5 | 8,369 | 809 | 1,920 | 2.37 | 4.36 | 18.55 | 223.59 |
| Raw | V5 | 7 | 88.36 | 1,503 | 432 | 491 | 1.14 | 2.82 | 7.30 | 282.31 |
| Cmps | V5 | 9 | 88.36 | 1,503 | 362 | 448 | 1.24 | 3.02 | 8.65 | 230.68 |
| Raw | V6 | 4 | 76.2 | 1,590 | 747 | 718 | 0.96 | 0.56 | -6.28 | 417.92 |
| Cmps | V6 | 7 | 76.2 | 1,590 | 662 | 653 | 0.99 | 0.66 | -2.85 | 355.64 |
| Raw | V7 | 5 | 59 | 589 | 243 | 208 | 0.85 | 2.11 | 4.03 | 181.51 |
| Cmps | V7 | 7 | 59 | 589 | 289 | 215 | 0.75 | 1.03 | -1.40 | 220.45 |
| Raw | V8 | 9 | 26 | 621 | 140 | 196 | 1.40 | 2.69 | 6.73 | 72.84 |
| Cmps | V8 | 12 | 26 | 621 | 154 | 170 | 1.10 | 2.38 | 6.25 | 92.82 |
| Raw | V9 | 9 | 53.6 | 1,114 | 410 | 373 | 0.91 | 1.26 | 0.17 | 262.12 |
| Cmps | V9 | 11 | 53.6 | 894 | 358 | 255 | 0.71 | 0.88 | 0.72 | 261.56 |
| Raw | VNW | 102 | 5 | 4,030 | 369 | 612 | 1.7 | 3.6 | 15.7 | 154.7 |
| Cmps | VNW | 112 | 5 | 3,361.897 | 360.661 | 540.246 | 1.5 | 3.31 | 12.91 | 169.247 |

### 14.4.3 Top Cuts

Due to the high-grade nature of the deposit, it was preferable to limit top cutting to avoid smoothing silver values within the true high-grade pockets of mineralisation. Very high grades form a genuine part of the sample population.

Log probability plots were analysed for the Vertikalny central and Vertikalny northwest domains (Figure 14.14 and Figure 14.15). . Two inflection points were noted in the Vertikalny central domains: one at approximately 6,000 g/t, and one at approximately 10,000 g/t. Compositing was performed prior to top cutting in order to reduce the high-grade burden organically. The 10,000 g/t threshold was chosen and applied to the composited data, Figure 14.13.

**Figure 14.13 Log Histogram for Domain V1 Illustrating Capping Level**




This top cut only affected five samples. No capping was applied to the Vertikalny northwest domains.

**Figure 14.14 Log Probability Plot for Vertikalny Central Domains**

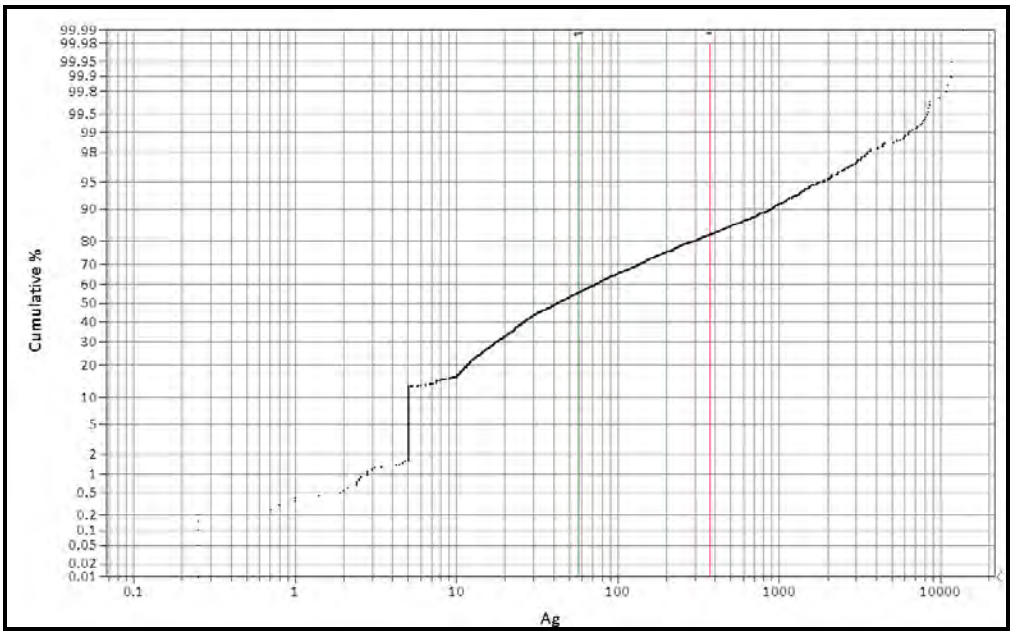
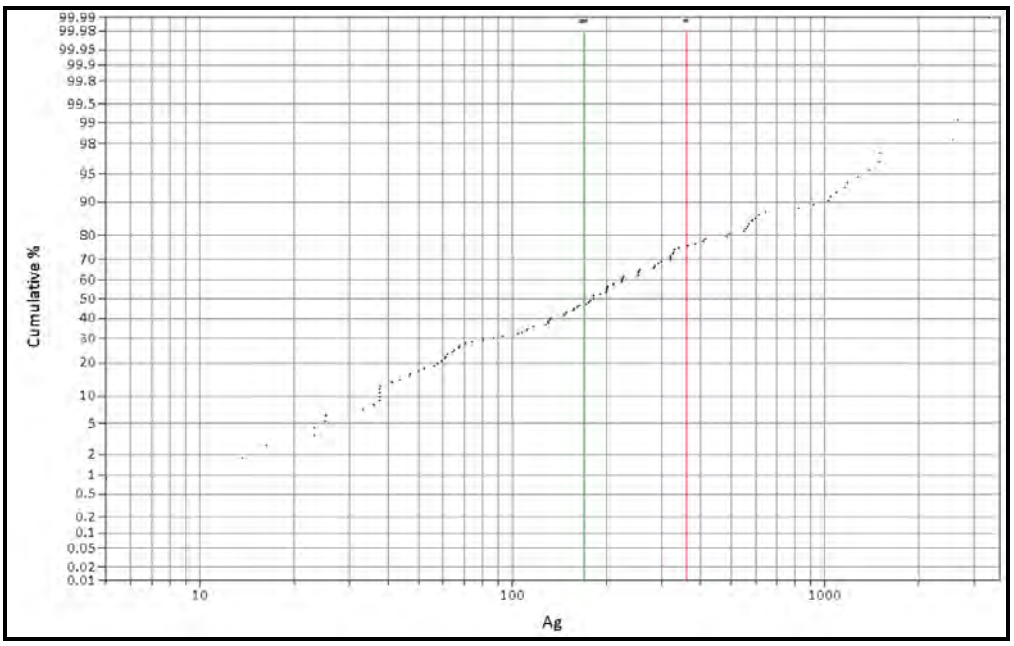



**Figure 14.15 Log Probability Plot for VNW Domain**




## 14.5 DENSITY

Specific gravity measurements from selected holes from the 2007 through 2015 drilling programs were provided by Silver Bear. In total, 375 measurements were included in the database. Density results per lithology group are presented in Table 14.5.

Density was estimated into the mineralised domains within the Vertikalny central area utilizing the IDW$^2$ method. Due to the low number of samples in the Northwest

Zone, density for that zone was assigned at the mean value for the density measurements within the mineralised domain 3.2 t/m³. The volume weighted average estimated density within the Vertikalny central domains is 3.65 t/m³.

Mean density values for each lithology were assigned to the waste blocks using geological wireframe models as a constraints.

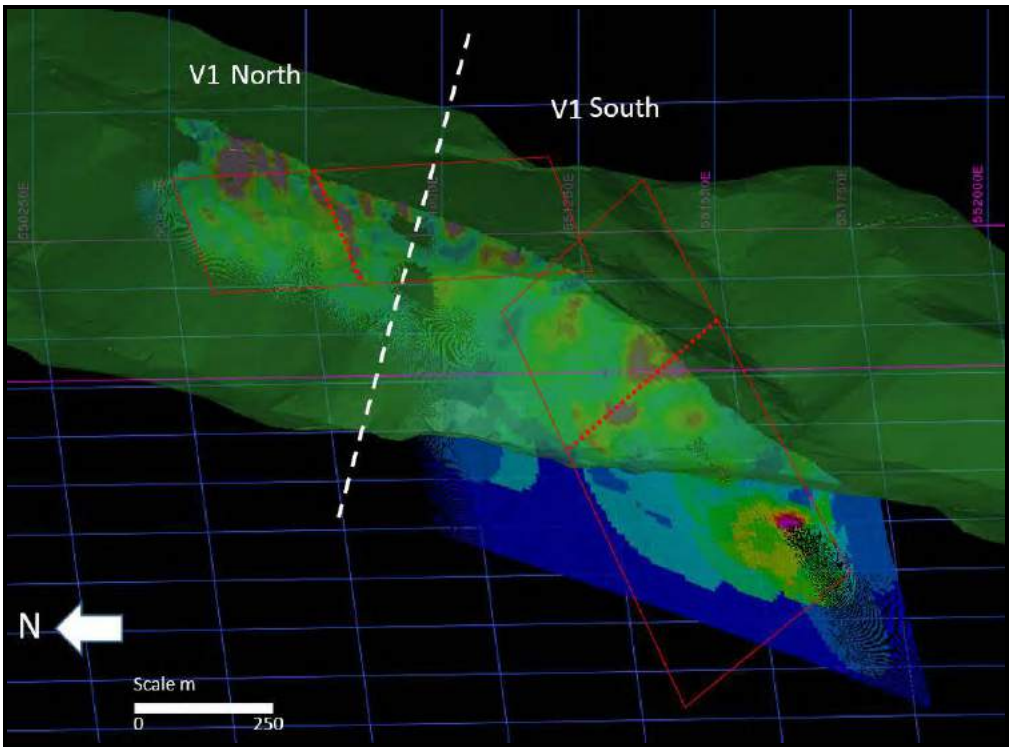
**Table 14.5 Mean Density Values per Lithology Group**

| Lithology | Mean Density Value (t/m3) |
|---|---|
| Breccia | 3.7 |
| Igneous | 3.0 |
| Mineralisation | 3.5 |
| Sediments | 2.7 |
| Mean | 3.2 |

## 14.6 VARIOGRAPHY

Variography was completed in Surpac Version 6.7. Experimental variograms were produced using drillhole composite data subjected to a normal scores transformation. Variograms were developed in plan view initially, with the strike, dip and plunge established independently thereafter. The nugget value has been established from a downhole variogram. For the main mineralised domain at Vertikalny central (V1), it was interpreted that the distribution of high grade mineralisation is controlled by oblique structures intersecting the mineralised vein. This interaction of structures produces different grade distributions in the northern part of the structure compared to the southern area. For variography the V1 domain was sub-divided into 'V1 North' and 'V1 south', Figure 14.16.

**Figure 14.16 3D Isometric View Illustrating the Theoretical Interaction between the Mineralised Vein and the Oblique Structure**

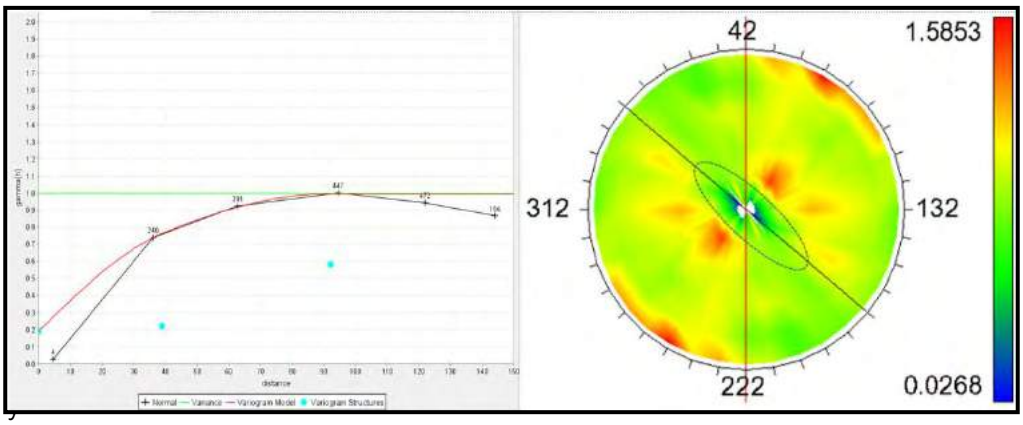



Notes: Red lines show a schematic representation of the oblique structures, with the red dashed line representing the theorectical intersection between the structures and the mineralised vein. White dashed line illustrates where the V1 domain was sub-divided for variography.

The modelled structures were used to establish the variogram structures to be used within the kriging estimation.

Figure 14.17 illustrates an example semi-variogram and variogram map for the V1 domain.

**Figure 14.17 Semi Variogram and Associated Variogram Map for V1 North – Major Direction**




Strong directional control has been established within the silver grade distribution. Table 14.6 presents the variogram parameters used for the estimation.

**Table 14.6 Directional Variogram Parameters**

| Zone | Major Direction | Plunge | Dip | Nugget | Range 1 | Sill 1 | Range 2 | Sill 2 | Semi-major Ratio |
|---|---|---|---|---|---|---|---|---|---|
| V1 South | 139 | 39.4 | 0 | 0.2 | 35 | 0.22 | 92 | 0.58 | 1.67 |
| V1 North | 121 | -49 | 0 | 0.2 | 5 | 0.015 | 50 | 0.65 | 1.42 |
| H1 | 108 | -68 | 0 | 0.2 | 130 | N/A | N/A | N/A | 2 |
| V2-V10 | 108 | -68 | 0 | 0.2 | 130 | N/A | N/A | N/A | 2 |

## 14.7 RESOURCE BLOCK MODELS

Two separate block models were constructed in Surpac, one for the Vertikalny Northwest Zone and a second for the Central Zone. The block model parameters are given in Table 14.7 and Table 14.8.

**Table 14.7 Vertikalny Central Block Model Parameters**

| Type | Y | X | Z |
|---|---|---|---|
| Minimum Coordinates | 7282628 | 551717 | 450 |
| Maximum Coordinates | 7286008 | 552850 | 1250 |
| User Block Size | 10 | 1 | 10 |
| Minimum Block Size | 2.5 | 0.25 | 2.5 |
| Rotation | -45 | 0 | 0 |

**Table 14.8 Vertikalny Northwest Block Model Parameters**

| Type | Y | X | Z |
|---|---|---|---|
| Minimum Coordinates | 7285000 | 549400 | 600 |
| Maximum Coordinates | 7286600 | 549900 | 1400 |
| User Block Size | 10 | 1 | 10 |
| Minimum Block Size | 2.5 | 0.25 | 2.5 |
| Rotation | -53 | 0 | 0 |

Standardised sub-cell splitting to the minimum block sizes presented in Table 14.7 and Table 14.8 was employed. Sub-cells received parent cell grades during estimation. Table 14.9 presents a comparison of the block model and wireframe volumes. The large parent cell is selected for best Kriging performance during the grade interpolation, whilst the smaller sub-cell maintains consistency between the final block volumes and the wireframe volume.

**Table 14.9 Comparison of Block Model and Wireframe Volume**

| Domain | Block Model Volume (m³) | Wireframe Volume (m³) | Percentage Difference in Volume (%) |
|---|---|---|---|
| H1 | 4,544,650 | 5,018,370 | 100.0 |
| V1 | 473,722 | | |
| V10 | 1,158 | 1,163 | 100.4 |
| V2 | 38,303 | 38,437 | 100.3 |
| V3 | 25,708 | 25,716 | 100.0 |
| V4 | 5,178 | 5,118 | 98.8 |
| V5 | 5,480 | 5,699 | 104.0 |
| V6 | 2,942 | 2,925 | 99.4 |
| V7 | 12,245 | 12,208 | 99.7 |
| V8 | 15,805 | 15,749 | 99.6 |
| V9 | 29,927 | 29,867 | 99.8 |
| VNW | 193,669 | 193,927 | 99.87 |

### 14.7.1 INTERPOLATION STRATEGY

Grades were estimated using OK, adopting a multi-pass methodology. The kriging employed the variogram parameters as presented in Section 14.6. Each of the domains was estimated independently.

QKNA was used to optimise the block size, the number of informing samples, discretisation, and search distances used in the estimation.

Quantitative measures of the kriging performance (e.g. slope of regression, kriging efficiency, kriging variance, block variance, proportion of negative weights) were used to test the appropriateness and optimise the kriging parameters. The analysis was carried out on large representative portions of the block model, as well as on isolated test blocks. Where test blocks were used, these were chosen as examples of one well informed block and one poorly informed block.

A summary of the estimation strategy is show in Table 14.10.

**Table 14.10 Estimation Parameters**

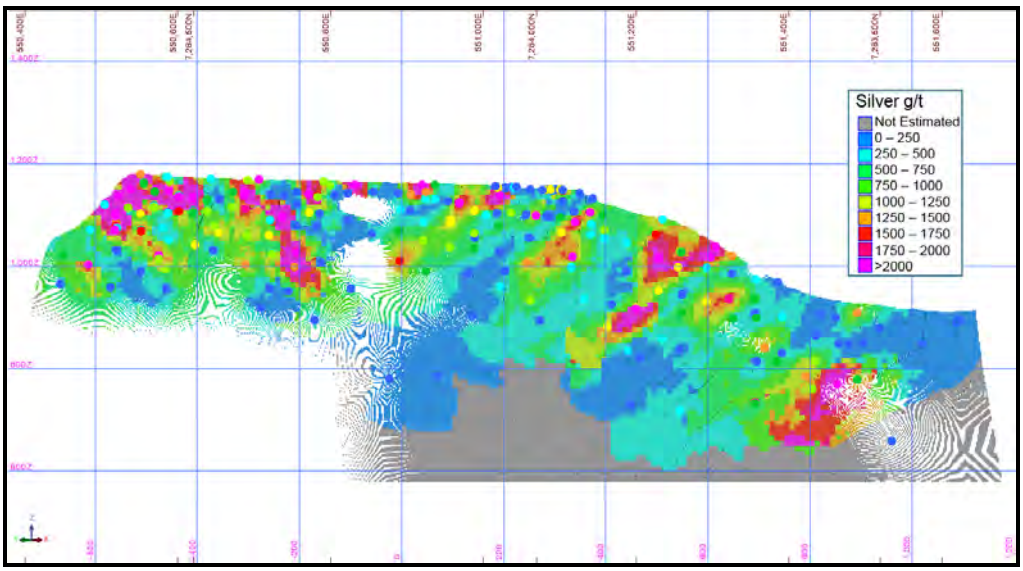
| Domain | Pass Number | Samples Numbers | | Search (m) | Descritisation | Maximum Samples per ID | Variogram Model |
|---|---|---|---|---|---|---|---|
| | | Minimum | Maximum | | | | |
| V1 North | 1 | 3 | 8 | 160 | x1,y3,z3 | 2 | V1 North Model |
| V1 North | 2 | 3 | 8 | 75 | x1,y3,z3 | 2 | V1 North Model |
| V1 North | 3 | 3 | 8 | 35 | x1,y3,z3 | 2 | V1 North Model |
| V1 South | 1 | 3 | 8 | 160 | x1,y3,z3 | 2 | V1 South Model |
| V1 South | 2 | 3 | 8 | 92 | x1,y3,z3 | 2 | V1 South Model |
| V1 South | 3 | 3 | 8 | 60 | x1,y3,z3 | 2 | V1 South Model |
| H1 | 1 | 3 | 8 | 195 | x1,y3,z3 | 2 | H1 Model |
| H1 | 2 | 3 | 8 | 130 | x1,y3,z3 | 2 | H1 Model |
| H1 | 3 | 3 | 8 | 85 | x1,y3,z3 | 2 | H1 Model |
| V2-V10 | 1 | 3 | 10 | 130 | x1,y3,z3 | 2 | H1 Model |
| VNW | 1 | 3 | 8 | 160 | x1,y3,z3 | 2 | V1 North Model |
| VNW | 2 | 3 | 8 | 75 | x1,y3,z3 | 2 | V1 North Model |
| VNW | 3 | 3 | 8 | 35 | x1,y3,z3 | 2 | V1 North Model |

## 14.8 BLOCK MODEL VALIDATION

Block model validation was completed using graphical and statistical methods, to confirm that the estimated block model grades appropriately reflect the local composite grades.

Graphical analysis of the informing samples versus estimated block grades was completed using long sections (Figure 14.18 and Figure 14.19).

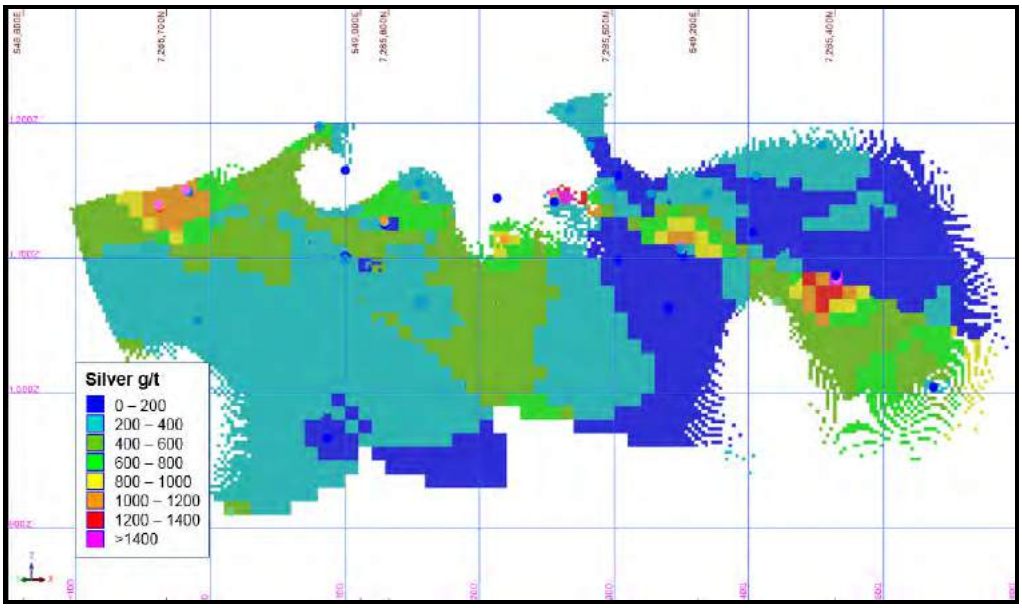
**Figure 14.18 Long Section Showing Composites and Estimated Block Grades for Vertikalny Central**




Notes: Vertical and horzontal grid lines are at 200m intervals.

The visual inspection demonstrated excellent correlation between composite and block grades. The anisotropic directionality noted in the variography can be clearly shown in Figure 14.19 where the anisotropy is reflected in the grade distribution.

**Figure 14.19 Long Section Showing Composites and Estimated Block Grades for Vertikalny Northwest**




Note: Vertical and horizontal gridlines at 100 m
Looking northeast

A comparison was made between the informing composites and the estimated block grades using a range of statistical measures. Table 14.11 presents a comparison between the informing composites and the estimated block grades for the Indicated Resource blocks within Vertikalny Central.

**Table 14.11 Statistics Comparing Block Estimate and Composite Grades**

| Data | Domain | Count | Min | Max | Mean | Std Dev | CV | Skewness | Kurtosis | Geom Mean | Median |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Block Model | H1 | 528,760 | 1 | 1,744 | 59 | 62 | 1.05 | 6.22 | 92 | 42 | 43 |
| Composites | H1 | 1,770 | 0 | 4,393 | 72 | 177 | 2.44 | 13.19 | 263 | 30 | 28 |
| Block Model | V1 | 171,852 | 12 | 7,129 | 842 | 774 | 0.92 | 2.32 | 9 | 562 | 646 |
| Composites | V1 | 499 | 12 | 13,054 | 1,256 | 1,727 | 1.38 | 3.02 | 12 | 534 | 687 |
| Block Model | V2-V10 | 35,591 | 16 | 2,818 | 354 | 173 | 0.90 | 2.75 | 16 | 153 | 160 |
| Composites | V2-V10 | 153 | 5 | 8,369 | 440 | 626 | 1.87 | 3.40 | 13 | 132 | 128 |
| Block Model | VNW | 52,933 | 42 | 1,619 | 352 | 202 | 0.57 | 1.71 | 5 | 302 | 295 |
| Composites | VNW | 87 | 5 | 3,362 | 436 | 590 | 1.35 | 2.95 | 10 | 216 | 225 |

Notes: Table 14.9 assesses Vertikalny Central Indicated Resource blocks only.

A number of the measures indicate a reduction in variance. This is a result of the change of support associated with the estimation process and the kriging interpolation. There is a reduction in the mean silver grade from composites to block estimate due to the de-clustering effect of the OK. Overall, the statistics present good conformance.

### 14.8.1 SWATH PLOTS

Swath plots have been used to assess the differences and similarities between the OK block estimate silver grade and the informing composite grades (Figure 14.20 and Figure 14.21).

**Figure 14.20 Northing Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Central**

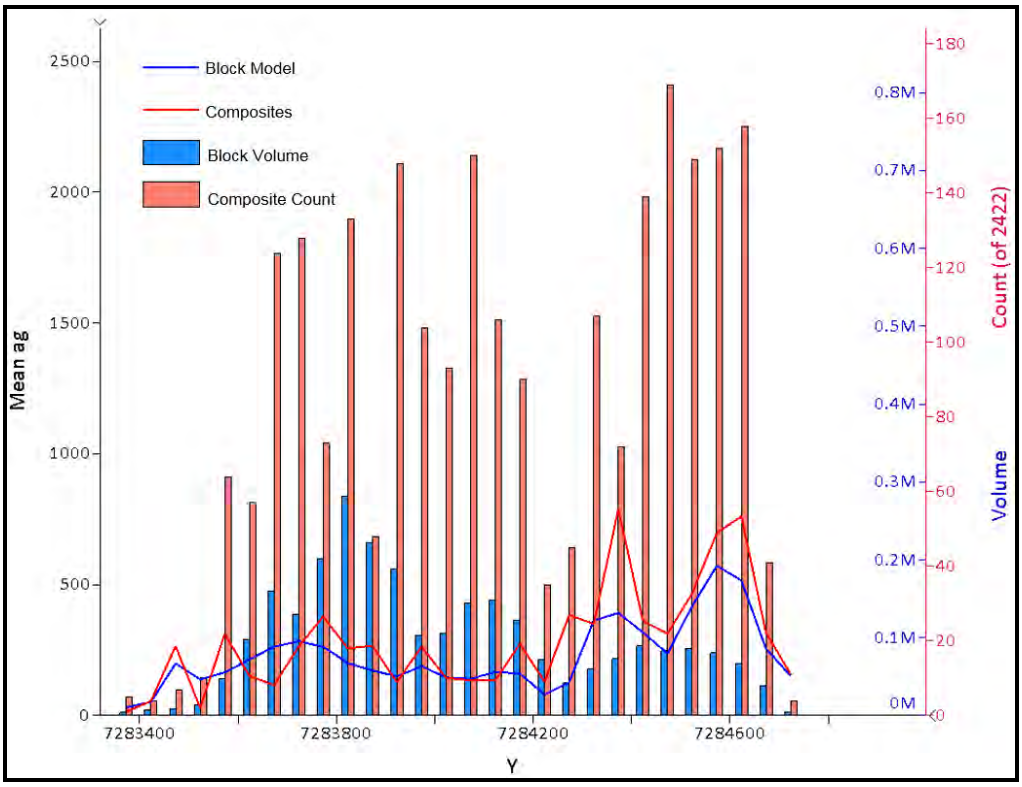


**Figure 14.21 Easting Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Central**

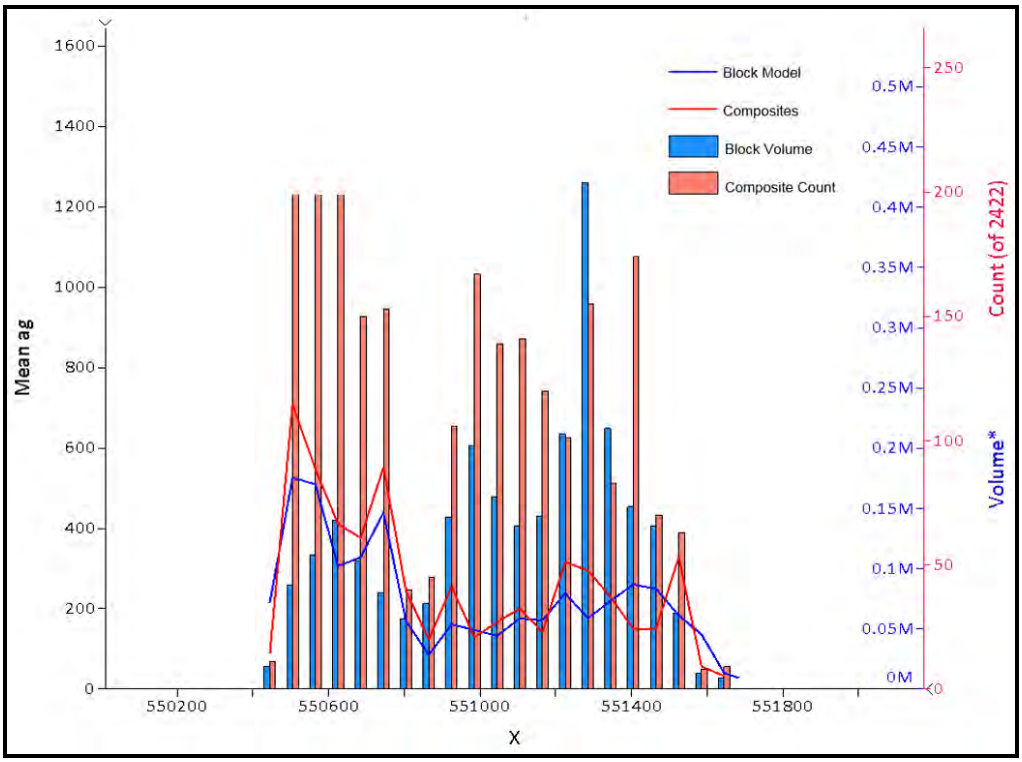
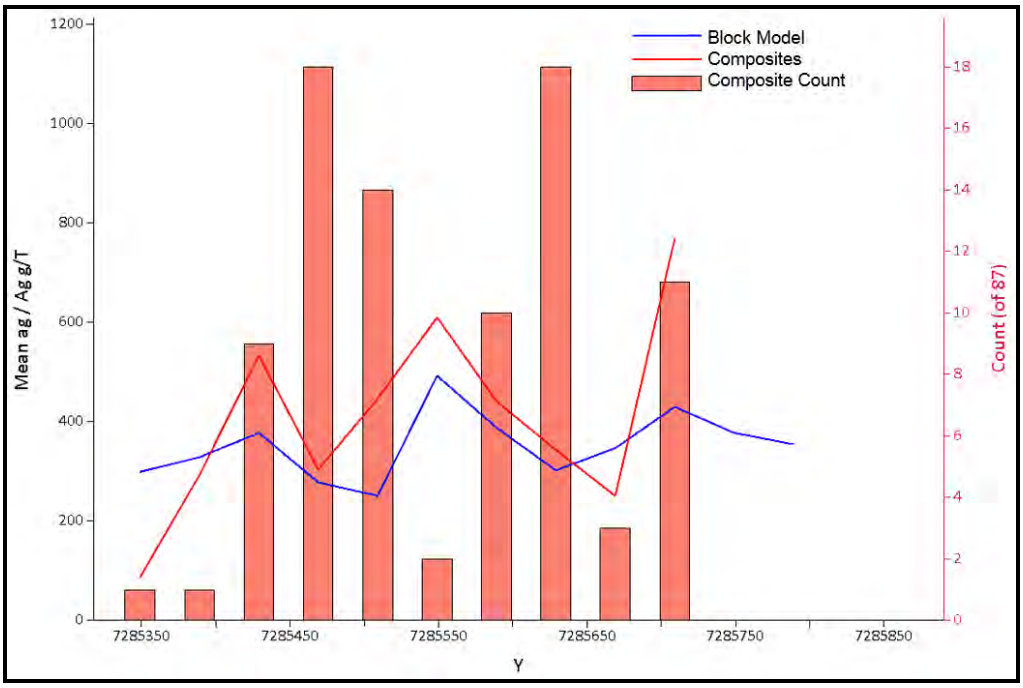



**Figure 14.22 Northing Swath Plot Comparing the Informing Composite and the OK Estimated Silver Grades for Vertikalny Northwest**



The swath plots for Vertikalny Central present good conformance between informing composites and estimated block grades. The swath plots for Vertikalny Northwest showed poorer conformance due to the impertinent mineralisation and paucity of data.

### 14.8.2 Conclusion

The various comparators described in the foregoing subsections serve to illustrate that the block model estimates are robust and satisfactorily models the distribution and variability of the informing sample grades without undue bias or smoothing. The models are suitable for the current level of development.

## 14.9 Mineral Resource Classification

The resource model was classified according to CIM Definition Standards on Mineral Resources and Mineral Reserves (CIM 2014).

A large proportion of the Mineral Resource within Vertikalny Central has been classified as Indicated. In this part of the deposit the nature, quality, amount, and distribution of data are such as to allow confident interpretation of the geological framework, and to assume continuity of mineralisation. Confidence in the estimate is sufficient to allow application of modifying factors within future technical and economic studies.

The remaining Mineral Resource, and all of the Vertikalny Northwest Mineral Resource are classified as Inferred. The mineralisation has been identified and limited measurements and sampling completed, but the data is insufficient to allow the geological and grade continuity to be confidently interpreted. It would be reasonable to expect that the majority of Inferred Mineral Resources would be upgraded to Indicated Mineral Resources with continued exploration; however, due to the uncertainty of Inferred Mineral Resources it should not be assumed that such upgrading will always occur.

Confidence in the estimate of Inferred Mineral Resources is not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning in prefeasibility or feasibility studies.

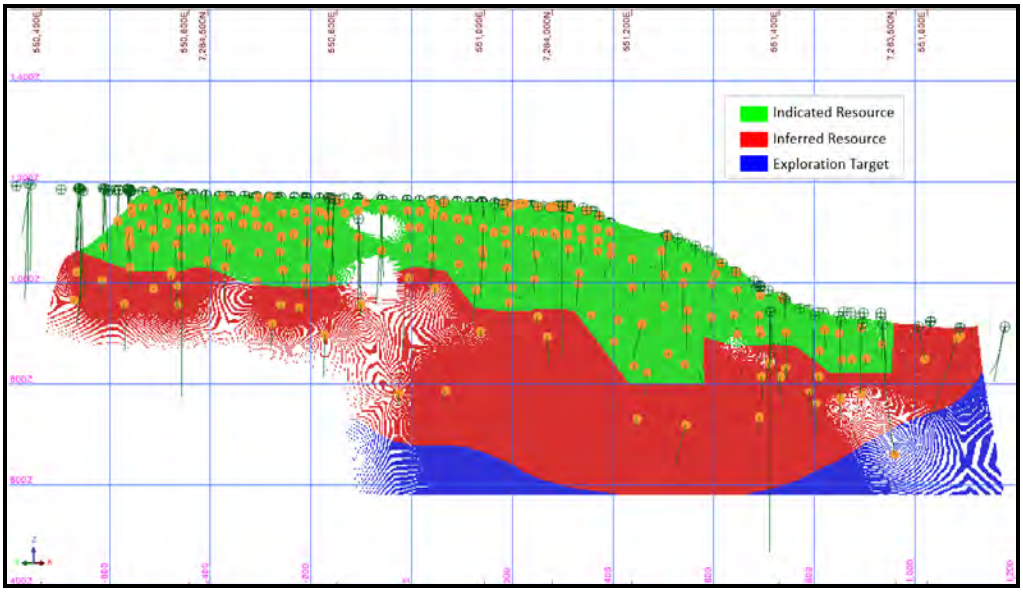
To classify the Mineral Resources, wireframe models have been generated to represent the limit of the Indicated and Inferred Resources. The models consider the following criteria:

- confidence in the sampling data and geological interpretation
- analysis of variogram parameters
- the data distribution (based upon graphical analysis and quantitative assessment of nearest and average distances to informing composites)
- kriging efficiency and slope of regression.

The wireframe models reflect the trends in the classification parameters as presented on a block by block basis, while ensuring that the classification resulted in appropriately coherent units. Figure 14.23 presents the scheme of Mineral Resource

Classification for the main structure at Vertikalny Central. The subordinate structures (domains V2-V10) and Vertikalny northwest are classified in the Inferred Resource category.

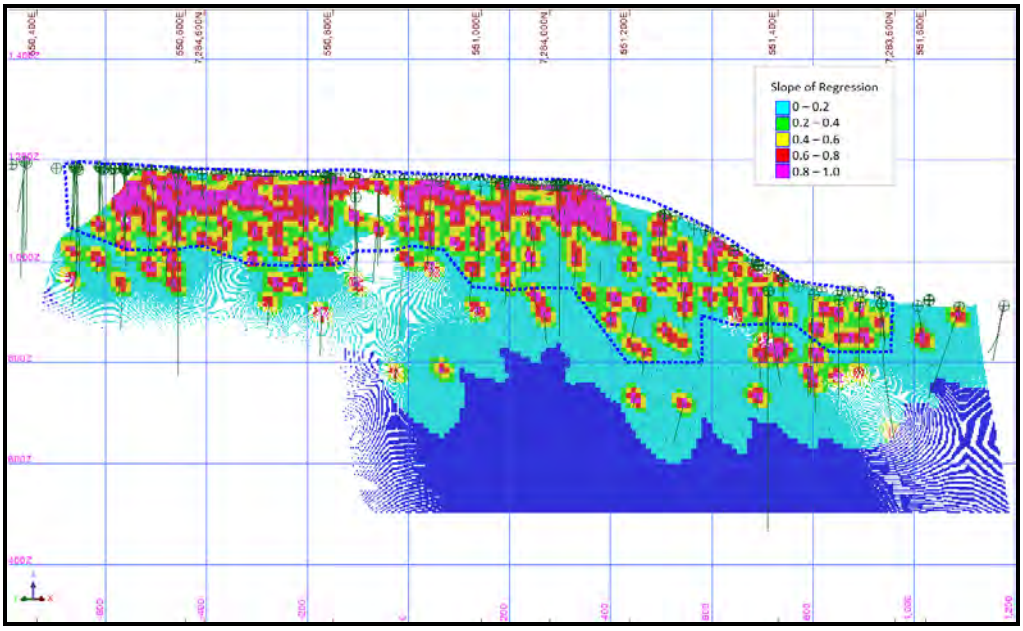
**Figure 14.23 Long Section of the Mineral Resource Classification for Vertikalny Central**




Note: Looking northeast

Figure 14.24 presents a long section illustrating the adopted resource classification and the slope of regression.

**Figure 14.24 Long Section of the Mineral Resource Classification and Slope of Regression**




Notes: Dashed blue line shows the limit of the Indicated Resource. Looking Northeast

## 14.10 MINERAL RESOURCE TABULATION

### 14.10.1 CUT-OFF GRADES

In order to demonstrate that the deposit has reasonable prospects for economic extraction a cut-off grade of 200 g/t silver has been applied for resources contained within an open pit shell at Vertikalny Central or within 80 m of surface at Vertikalny Northwest. A 350 g/t silver cut-off has been applied for the underground resource

The resource pit shell used to constrain the open pit resource at Vertikalny Central uses the following assumptions:

- silver price of $19.00/troy oz
- mining recovery 95%
- waste dilution 30%
- mining cost of US $2.53/t
- processing cost of US $52.00/t
- general and administration costs of US $40.60/t
- royalty of 6.5%
- overall silver recovery of 88%.

### 14.10.2 MINERAL RESOURCE TABULATION

The updated Mineral Resource for the Vertikalny deposit is summarised in Table 14.12. The effective date of the updated Mineral Resource is 8th July 2016.

**Table 14.12 Summary of Mineral Resources – Vertikalny Deposit**

| Zone | Assumed Mining Method | Cut-off Grade Ag (g/t) | Indicated Resources | | | Inferred Resource | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) |
| Vertikalny Central | Open Pit | 200 | 360,000 | 1,482 | 17,100,000 | 4,000 | 496 | 100,000 |
| | Underground | 350 | 340,000 | 959 | 10,600,000 | 350,000 | 789 | 8,800,000 |
| | All | - | 700,000 | 1,227 | 27,700,000 | 350,000 | 786 | 8,900,000 |
| Vertikalny Northwest | Open Pit | 200 | - | - | - | 110,000 | 430 | 1,600,000 |
| | Underground | 350 | - | - | - | 90,000 | 535 | 1,500,000 |
| | All | - | - | - | - | 200,000 | 476 | 3,100,000 |
| **Total** | **All** | **-** | **700,000** | **1,227** | **27,700,000** | **550,000** | **672** | **12,000,000** |

### 14.10.3 GRADE TONNAGE SENSITIVITY

The Vertikalny block models have been reported at a range of cut-offs to provide an indication of the grade-tonnage sensitivity (Table 14.13, Table 14.14, and

Table 14.15).

**Table 14.13 Vertikalny Central Indicated Blocks – Grade-Tonnage Sensitivity**

| Cut-off Ag Grade (g/t) | Tonnage (kt) | Ag Grade (g/t) | Contained Metal Ag (koz) |
|---|---|---|---|
| 150 | 1,046,000 | 892 | 30,010,000 |
| 200 | 852,000 | 1,057 | 28,940,000 |
| 250 | 773,000 | 1,142 | 28,370,000 |
| 300 | 707,000 | 1,222 | 27,790,000 |
| 350 | 661,000 | 1,285 | 27,310,000 |
| 400 | 627,000 | 1,334 | 26,900,000 |
| 450 | 595,000 | 1,383 | 26,470,000 |

Notes: Sensitivity numbers cannot be compared directly to the Mineral Resource tabulation in Table 14.12 because different cut-offs have been applied for open pit and underground resource blocks.

**Table 14.14 Vertikalny Central Inferred Blocks – Grade-Tonnage Sensitivity**

| Cut-off Ag Grade (g/t) | Tonnage (kt) | Ag Grade (g/t) | Contained Metal Ag (koz) |
|---|---|---|---|
| 150 | 628,000 | 539 | 10,880,000 |
| 200 | 518,000 | 617 | 10,270,000 |
| 250 | 460,000 | 667 | 9,860,000 |
| 300 | 378,000 | 754 | 9,160,000 |
| 350 | 351,000 | 786 | 8,880,000 |
| 400 | 333,000 | 809 | 8,650,000 |
| 450 | 312,000 | 835 | 8,370,000 |

Notes: Sensitivity numbers cannot be compared directly to the Resource tabulation in Table 14.12 because different cut-offs have been applied for open pit and underground resource blocks.

**Table 14.15 Vertikalny North West Inferred Blocks - Grade Tonnage Sensitivity**

| Cut-off Ag Grade (g/t) | Tonnage (kt) | Ag Grade (g/t) | Contained Metal Ag (koz) |
|---|---|---|---|
| 150 | 255,000 | 465 | 3,810,000 |
| 200 | 237,000 | 487 | 3,710,000 |
| 250 | 209,000 | 522 | 3,510,000 |
| 300 | 170,000 | 579 | 3,160,000 |
| 350 | 154,000 | 606 | 2,990,000 |
| 400 | 134,000 | 638 | 2,750,000 |
| 450 | 114,000 | 677 | 2,470,000 |

Notes: Sensitivity numbers cannot be compared directly to the Resource tabulation in Table 14.12 because different cut-offs have been applied for open pit and underground resource blocks.

In September 2012, June 2015 and March 2016, Tetra Tech estimated the Mineral Resource for the Nizhny Endybal Mangazeisky South and Mangazeisky North deposits, which are shown along with Vertikalny Central and Vertikalny Northwest estimates in Table 14.16 as a summary of the total Mineral Resources for the Property.

**Table 14.16 Total Resources for the Mangazeisky Property**

| Zone | Assumed Mining Method | Cut-off Grade Ag (g/t) | Indicated Resources | | | Inferred Resource | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) | Tonnes | Grade Ag (g/t) | Contained Metal Ag (troy oz) |
| Vertikalny Central | Open Pit | 200 | 360,000 | 1,482 | 17,100,000 | 4,000 | 496 | 100,000 |
| | Underground | 350 | 340,000 | 959 | 10,600,000 | 350,000 | 789 | 8,800,000 |
| Vertikalny Northwest | Open Pit | 200 | | | | 110,000 | 430 | 1,600,000 |
| | Underground | 350 | | | | 90,000 | 535 | 1,500,000 |
| Nizhny Endybal | Open Pit | 150 | | | | 710,000 | 316 | 7,200,000 |
| Mangazeisky North | Open Pit | 150 | 304,000 | 626 | 6,100,000 | 98,000 | 671 | 2,100,000 |
| Mangazeisky South | Open Pit | 150 | | | | 60,000 | 246 | 500,000 |
| **Total** | **All** | - | **1,004,000** | **1,046** | **33,800,000** | **1,422,000** | **477** | **21,800,000** |

In order to demonstrate that the deposit has reasonable prospects for economic extraction, a cut-off grade of 150 g/t was applied for the Mangazeisky North and Nizhny Endybal deposits, based upon the following assumptions:

- forecasted silver price of USD$17/troy oz silver
- open pit mining cost of $3.16/t
- processing cost of $50/t
- G&A costs of $12.50/t
- transport costs, from pit to process plant, of $3.60/t
- overall silver recovery of 80%.

The Mangazeisky North Mineral Resource Estimate was prepared by Mr. Robert Davies, B.Sc., EurGeol, CGeol. Mr. Davies is a Senior Resource Geologist at Tetra Tech and is the QP as defined by NI 43-101. Mr. Davies is the QP for the Mineral Resource for the Vertikalny deposits and for the revised Mineral Resource for the Nizhny Endybal deposit.

The effective date of the Mangazeisky North Resource is 31st March 2016. The effective date of the Mangazeisky South Resource is 3rd June 2015. The effective date of the Vertikalny Central and Northwest Mineral Resource is 10th February 2015. The effective date of the Nizhny Endybal Mineral Resource is 11th September 2012; however, this resource was re-stated with a higher cut-off grade on the 10th June 2015

## 14.11 GRADE-TONNAGE CURVES

Figure 14.25 and Figure 14.26 depict grade-tonnage curves for the Vertikalny Central Zone and Northwest Zone Mineral Resources.

**Figure 14.25 Grade-Tonnage Curve for Indicated & Inferred Resources at Vertikalny Central Zone**

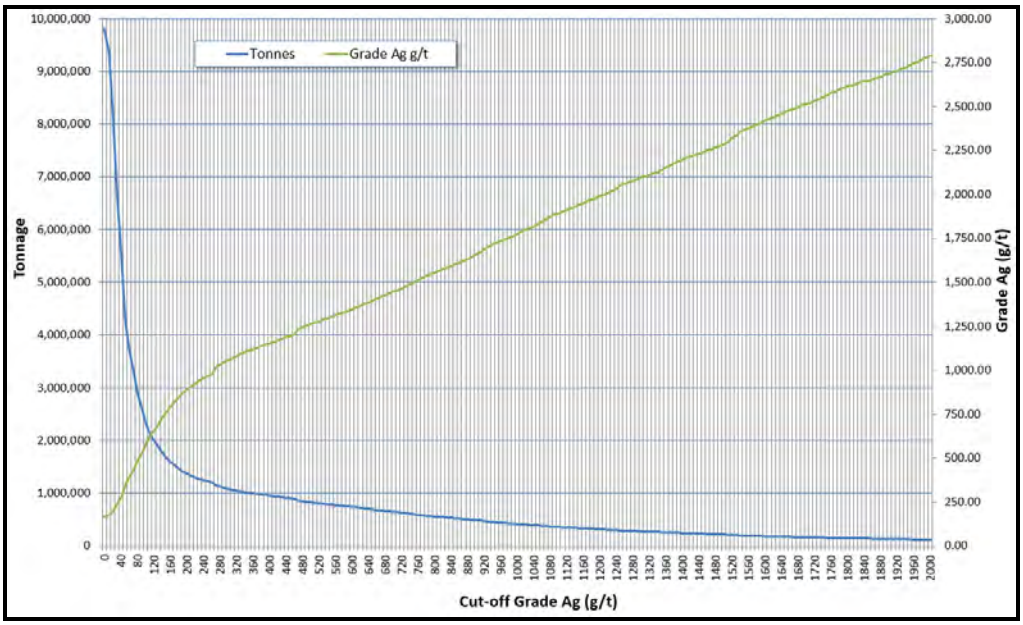
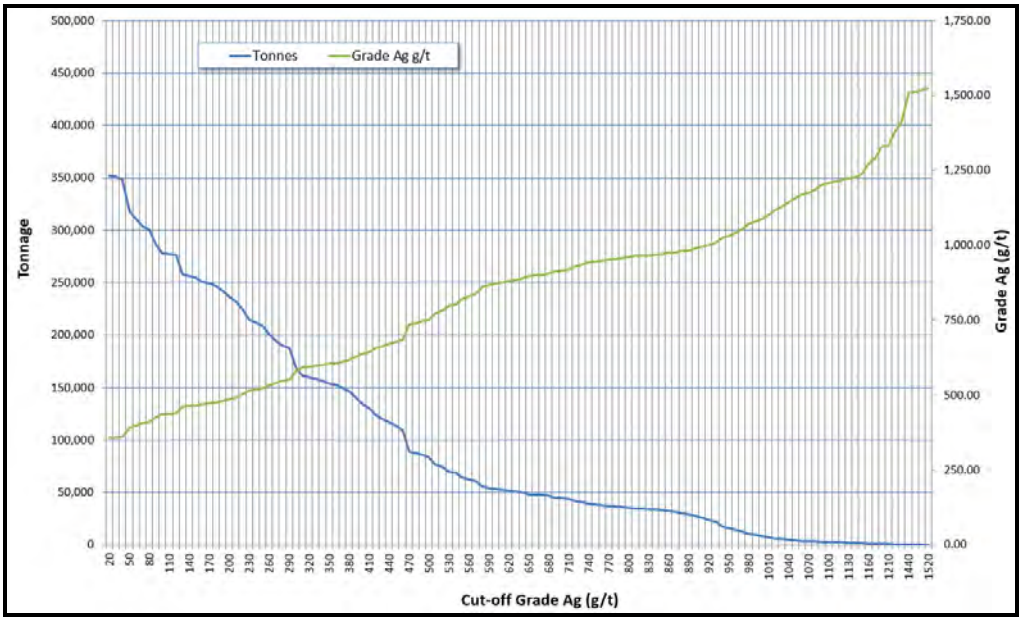



**Figure 14.26 Grade-Tonnage Curve for Inferred Resource at Vertikalny Northwest Zone**




Tetra Tech is not aware of any environmental, permitting, legal, title, taxation, socio-economic, marketing, or political factors that could materially affect the Mineral Resource.

# 15.0 MINERAL RESERVE ESTIMATES

## 15.1 CUT-OFF GRADE PARAMETERS

The input parameters used to calculate the open pit and underground cut-off grades are shown in Table 15.1 and Table 15.2, respectively.

**Table 15.1 Open Pit Cut-off Grade Calculation Parameters**

| Description | Unit | Value |
|---|---|---|
| Silver Price | USD/troy oz | 18.00 |
| Process Unit Cost | USD/t processed | 57.00 |
| Process Recovery | % | 85 |
| G&A Unit Cost | USD/t processed | 27.00 |
| Selling Cost | USD/troy oz | 0.50 |
| Royalty | % | 6.5 |
| Mining Dilution | % | 30 |

Note: To calculate the marginal cut-off grade for the open pit it has been assumed that approximately 33% of the G&A costs are associated with mining and therefore the G&A can be reduced to USD27/t ore processed.

**Table 15.2 Underground Cut-off Grade Calculation Parameters**

| Description | Unit | Value |
|---|---|---|
| Silver Price | USD/oz | 18.00 |
| Processing Unit Cost* | USD/t processed | 57.00 |
| Process Recovery | % | 85 |
| G&A Unit Cost* | USD/t processed | 40.00 |
| Underground Mining Unit Cost | USD/t mined | 53.00 |

Note: Costs at the time of the cut-of grade calculation. The final cost estimates may change.

### 15.1.1 OPEN PIT MINERAL RESERVE CUT-OFF

The open pit Mineral Reserves were estimated using the in situ rock inventory above the selected cut-off grade by applying 30% mining dilution at zero grade, and 5% mining losses.

The selected dilution and loss factors are as per Russian Mineral Reserve statement standards. In practice, while ore losses and dilution will occur during the mining operation, it is possible that the mining dilution factor be lower and part of the diluted material may contain mineralization.

The calculated marginal cut-off grade for the Project using the presented parameters in Table 15.4 is 240 g/t. The selected cut-off grade results in continuation of the orebody in some areas, allowing a more practical selective mining during the mining operation.

### 15.1.2 Underground Mineral Reserve Cut-off

Prior to developing a detailed mine design, analyses of the typical overall mining costs and the anticipated extraction factors such as mine extraction percentage and dilution, is required to develop an understanding of the diluted mineral grades that may contribute to the Project value.

Often these analyses are challenging, and even a 10% variation of the diluted grade may yield sub-economical areas. The mineralisation at Vertikalny typically consists of thin and steeply dipping structures; therefore, it was important to evaluate a number of different underground mining shapes over a range of cut-off grades using industry accepted and proven underground stope optimisation software, Datamine's Mineable Shape Optimizer (MSO).

Tetra Tech used both break-even cut-off grade and the marginal cut-off grade in the determination of the underground Mineral Reserve. The break-even cut-off grade is the lowest grade of material that can be mined and processed economically considering all applicable costs, without incurring a loss and is defined as follows:

*Break-even Cut-off Grade = Total Unit Operating Cost/(Unit Price x Recovery)*

The break-even cut-off grade was calculated as approximately 305 g/t silver.

The marginal cut-off grade is the lowest grade where the net revenue value of the metal recovered is equal to the cost of mining, crushing, loading, hauling, and processing. By implication it is assumed that in this case the G&A cost is sunk. The marginal cut-off grade calculation is as follows:

*Marginal Cut-off Grade = (Total Unit Operating Cost –G&A Costs)/(Unit Price x Recovery)*

The marginal cut-off grade was calculated as approximately 223 g/t silver.

In both cases, the cut-off grade corresponds to a diluted grade (i.e., the grade of the material that is available for processing or stockpiling).

Tetra Tech applied the break-even cut-off grade to 95% of the total mineable ore tonnes, and the marginal cut-off grade to 5% of the mineable ore tonnes, to derive an effective Mineral Reserve cut-off grade of 300 g/t silver. The Mineral Reserve cut-off grade was used as a diluted cut-off parameter in Datamine's MSO to develop the economical and practical mining shapes for the Vertikalny underground mine. Mining shapes with 300 g/t silver (diluted) or higher will add value if exploited and processed within the assumed economic environment. The calculation of the two cut-off grades are summarised in Table 15.3 and Table 15.4.

**Table 15.3 Break-even Mining Cut-off Grade Calculations**

| Calculation | Unit | Result |
|---|---|---|
| Total Underground Variable Mining Cost | USD | 24,394,683 |
| Underground Modified Ore Tonnes Planned | t | 457,981 |
| Minimum Mining Width Sub-level Open Stoping | m | 1.4 |
| Modification from Report (Dilution) | % | 33.33 |
| Processing Cost | USD/t | 57.00 |
| G&A Cost | USD/t | 40.00 |
| Process Recovery | % | 85 |
| Silver Price | USD/tr. oz | 18.00 |
| Calculation of Cut-off Grade (Diluted) | g/t Ag | 305 |

**Table 15.4 Marginal Mining Cut-off Grade Calculations**

| Calculation | Unit | Result |
|---|---|---|
| Total Underground Variable Mining Cost | USD | 24,394,683 |
| Underground Modified Ore Tonnes Planned | t | 457,981 |
| Minimum Mining Width Sub-level Open Stoping | m | 1.4 |
| Modification from Report (Dilution) | % | 33.33 |
| Processing Cost | USD/t | 57.00 |
| G&A Cost | USD/t | 40.00 |
| Process Recovery | % | 85 |
| Silver Price | USD/tr. oz | 18.00 |
| Calculation of Cut-off Grade (Diluted) | g/t Ag | 223 |

The key input parameter used for the development of the mining stopes is the 300 g/t silver (diluted) cut-off grade. The Datamine MSO software considers low-grade material as dilution; therefore, dilution does not necessarily occur at 0 g/t silver grades in all areas of the stopes. Where Inferred Mineral Resources or waste is included, the dilution grade was set to 0 g/t silver.

Note that the 300 g/t silver diluted cut-off grade corresponds to approximately 450 g/t in-situ cut-off grade.

## 15.2 MINERAL RESERVE STATEMENT

The Mineral Reserve was estimated in accordance with CIM Definition Standards for Mineral Resources and Mineral Reserves (prepared by the CIM Standing Committee on Reserve Definitions, Adopted by CIM Council on November 27, 2010). According to the CIM, a Mineral Reserve is the economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a prefeasibility study. This study must include adequate information on mining, processing, metallurgical, economic, and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined. The Mineral Reserve is inclusive of the reported Mineral Resource.

Proven and Probable Mineral Reserves for the Vertikalny deposit are presented in Table 15.5.

**Table 15.5 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016**

| Category | Cut-off Grade (g/t Ag) | Ore (t) | Ag Grade (g/t) | Ag Metal Content (koz) |
|---|---|---|---|---|
| Probable – Open Pit | 240 | 364 | 1,209 | 14,144 |
| Probable – Underground | 450 | 458 | 569 | 8,375 |
| **Total Mineral Reserves** | - | **822** | **852** | **22,519** |

# 16.0 MINING METHODS

## 16.1 OPEN PIT MINING

### 16.1.1 OPEN PIT MINING METHOD SELECTION

A conventional mining method operation consisting of drill and blast, load and haul is planned for the open pit. The mining operation will be carried out as an owner operated whilst the blasting operation will be carried out using a blasting contractor until an owner blasting crew is employed during the mine operation.

The deposit is approximately 1 km in length and ranges in width between 0.5 to 8.0 m. This geometry will require selective mining, accurate grade control and relatively smaller load-and-haul equipment to minimise the mining dilution and losses.

Drilling and blasting is planned in 10-m benches, with a blasthole diameter of 76 mm. Loading will be carried out in four, 2.5-m stacks or three, 3.3-m intervals using backhoe excavators. Twenty-tonne trucks were selected for waste and ore haulage. Following test blasts during pre-production, the option of blasting on 5 m will be investigated. Tetra Tech believes that this will not materially change the operating cost estimate and may have advantages for grade control. Double benching on the final pit wall could also be considered.

The ROM will either be hauled directly to the crusher or stockpiled next to the crusher to be used when required. The waste rock and the low-grade mineralised rock (resource balance as per Russian standards) will be hauled to the WRD and low-grade stockpile area.

### 16.1.2 PIT SLOPE CHARACTERISATION

SRK developed the open pit and underground geotechnical design criteria that were presented in the 2016 Mangazeisky Project Feasibility Study (Appendix B). This section presents a summary of the work carried out for open pit mining. The result of the kinematic analyses highlight that the maximum overall slope angle is constrained by the bench and berm geometry and inter-ramp angles (IRAs), which are based on the requirement to minimise kinematic instability and trap potential rock fall. Based on the analyses, the overall angles for the pit slope are presented in Table 16.1.

The maximum IRA of 56° is recommended for the hanging wall. Due to planar instability along bedding plans in the footwall, the maximum IRA for the footwall is set to 48°. Steeper slopes will start to undercut the bedding on an inter-ramp scale that could generate major instability.

**Table 16.1 Recommended Slope Angles**

| Zone | Bench Height (m) | Bench Face Angle (°) | Berm Width (m) | IRA (°) |
|---|---|---|---|---|
| Hanging Wall | 20 | 80 | 10 | 56 |
| Footwall | 20 | 70 | 11 | 48 |

Both sets of design geometry do not take ramps into account. For trenches, where hard rock is present, the criteria for the hanging wall and footwall shown in Table 16.1 will be used.

### 16.1.3 PIT OPTIMISATION

#### *APPROACH*

Pit optimisation was carried out on the updated orebody model using the GEOVIA Whittle™ software, to verify the economic portion of the orebody to be mined via open pit methods.

The application of the Lerchs-Grossmann algorithm provided a number of cones targeting the higher grade part of the deposit that were not practical for an open pit mine design and operation. The key to unlocking the value of the underlying ore body using an open pit was to use a slot type ramp configuration, instead of the conventional spiral ramp concept, that connected the identified individual cones into a single pit. While part of the slot type ramp adds to the waste rock in the pit design, it allows the pit slope angle to be maximised in the footwall and hanging wall, which results in an optimal strip ratio that still provides an economic open pit boundary. In addition it allows for a smoother integration with the underground mine design. In other words part of the waste stripping in the open pit could actually be considered as the amount of earth moving that could have been required to access the underground mine workings if there were no open pit.

The pit optimisation to define an economic boundary for the South Pit was carried out using shallower pit slope angles where in pit ramping system was necessary to access the mining benches.

#### *OPTIMISATION PARAMETERS*

The selected optimisation parameters are provided in Table 16.2.

**Table 16.2 Optimisation Parameters**

| Parameter | Unit | Value | |
|---|---|---|---|
| Average Unit Mining Cost | $/t mined | U2.50 | |
| Process Unit Cost | $/t processed | U57.00 | |
| G&A Unit Cost | $/t processed | U40.00 | |
| Royalty | - | 6.5% | |
| Selling Cost | $/tr. oz. | U0.50 | |
| Discount | - | 5% | |
| Mining Loss | - | 95% | |
| Dilution | - | 30% | |
| Process Recovery | - | 85.00% | |
| Silver Price | $/tr. oz | U18.00 | |
| **Overall Slope Angle** | **Unit** | **Base Case** | **Shallower Case** |
| Footwall | ° | 48 | 42 |
| Hanging Wall | ° | 56 | 50 |

The mining cost used in the optimisation is the average mine operating unit cost that was estimated in Tetra Tech (2016).

### *Optimisation Summary*

Initially, two optimisation scenarios were analysed based on the selected sets of pit slope angles: the base case slope angles as provided by SRK (Appendix B) and the alternative slope set approximately 6° shallower than the base case. The selected pit shell in the base case slope scenario was used as a guideline to design the North Pit and the generated pit shell from the shallower slope alternative was used for the South Pit design.

Owing to project time constraints, the optimisation analyses included both the North and South Pit areas together in each optimisation, and therefore the generated pit value in each case represents the overall pit operating cash flow. The North and South pit shells were selected to minimise the strip ratio while maintaining practical access to the open pit and underground operations.

A summary of the optimisation scenario results is presented in Figure 16.1, and Figure 16.2.

In both scenarios, pit shell 33 was selected as the optimal and practical pit boundary for the Project. The selected pit shell shown in Figure 16.1 was used for the design of the North pit and the selected shell shown in Figure 16.2 was used as a guideline for the South Pit design.

If open pit was the only mining method used to exploit the orebody, a larger pit shell could be selected as an optimal open pit boundary; however, the interaction with the underground mine design mitigated this decision.

A plan view of the selected pit shell contours for the pit design is presented in Figure 16.3.

**Figure 16.1 Optimisation Summary for the Base Case**

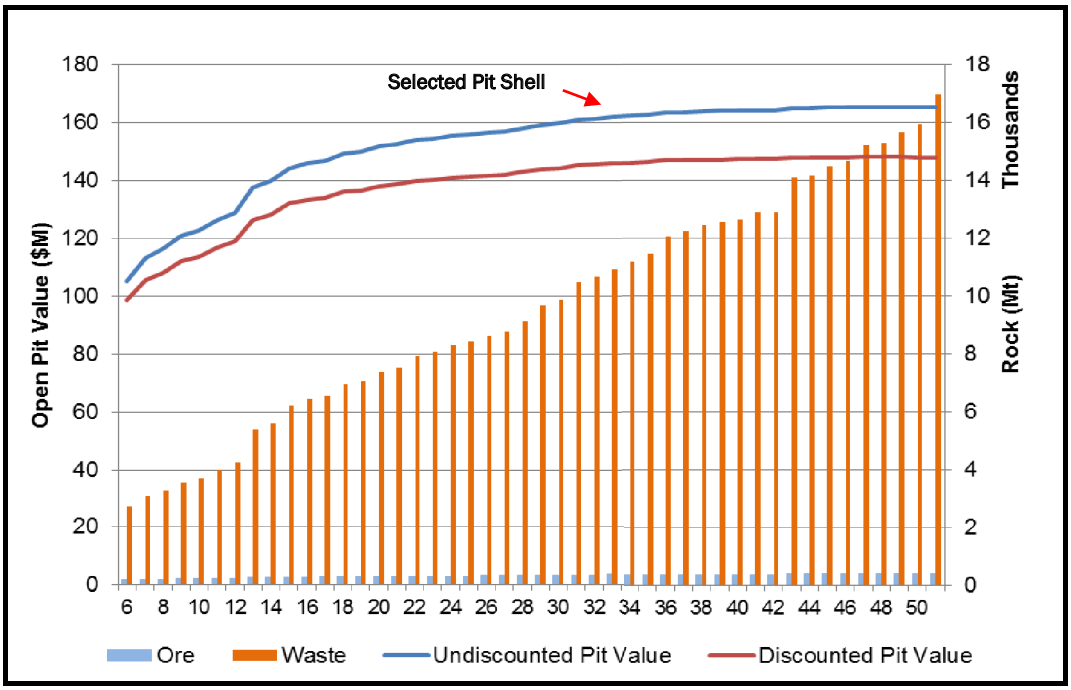



**Figure 16.2 Optimisation Summary for the Scenario using Shallower Slope Angle**

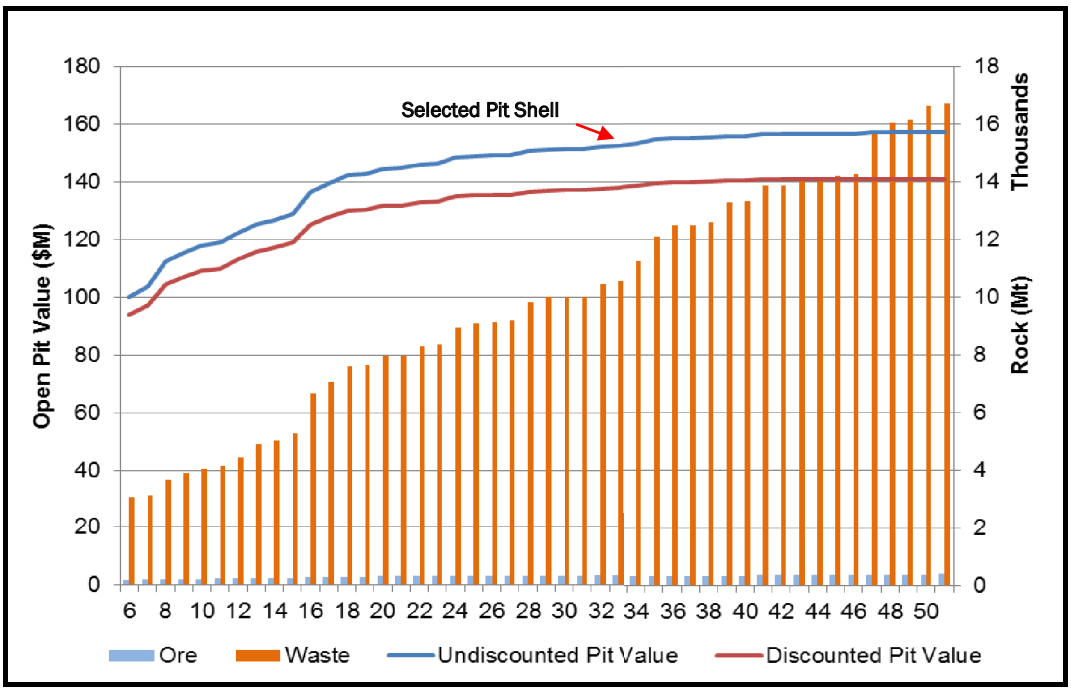
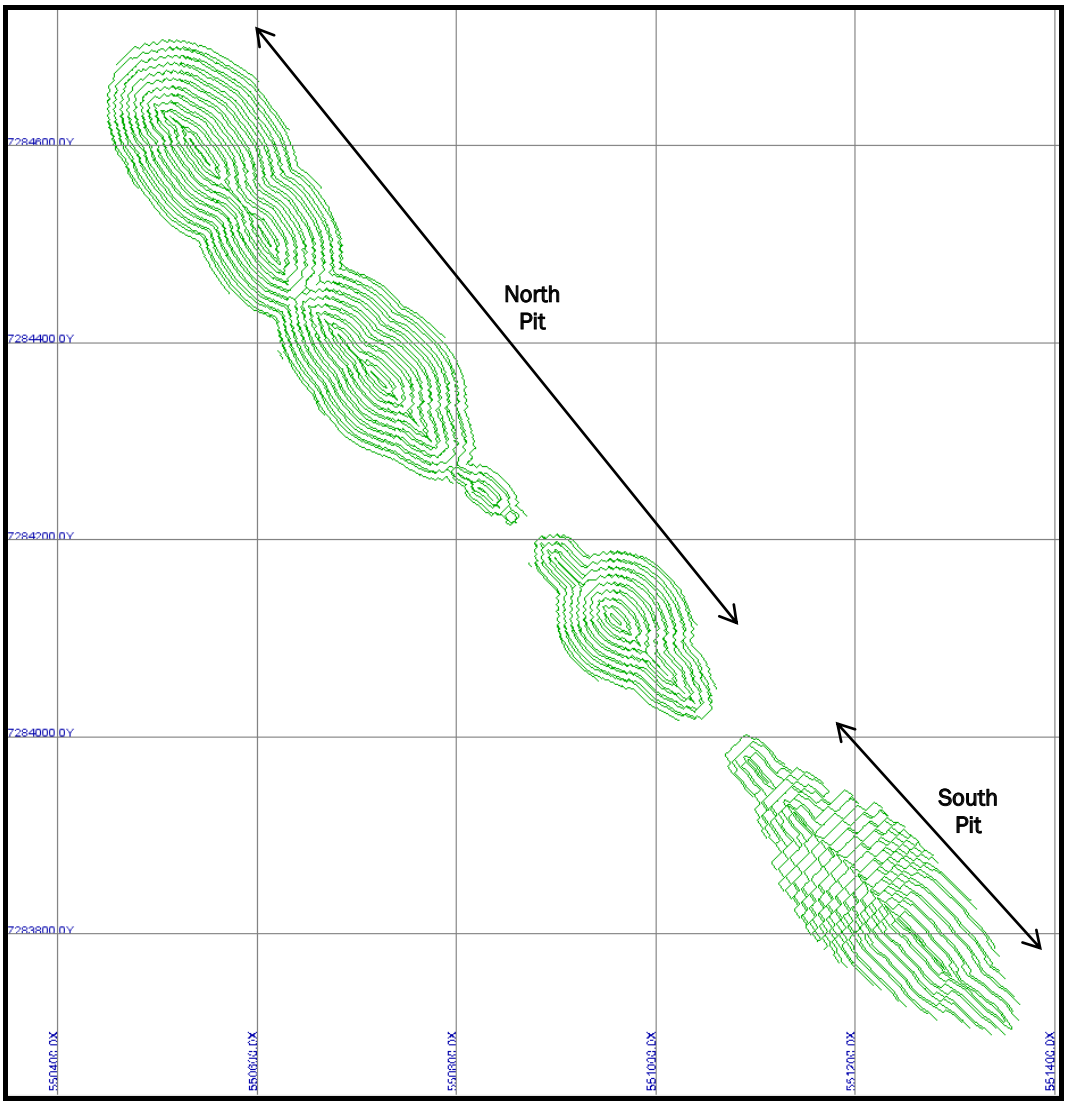


**Figure 16.3 Plan View of the Selected Pit Shell Contours**




In addition to the initial analyses, and as a final check, optimisation analysis was carried out using an average mining cost of $2.75/t mined on the base case scenario. The result of this analyses showed the effect of the higher mining cost on a pit shell with similar tonnes, as the selected base case, was approximately 1.8% less than the undiscounted pit value in the base case.

### *Sensitivity Analysis*

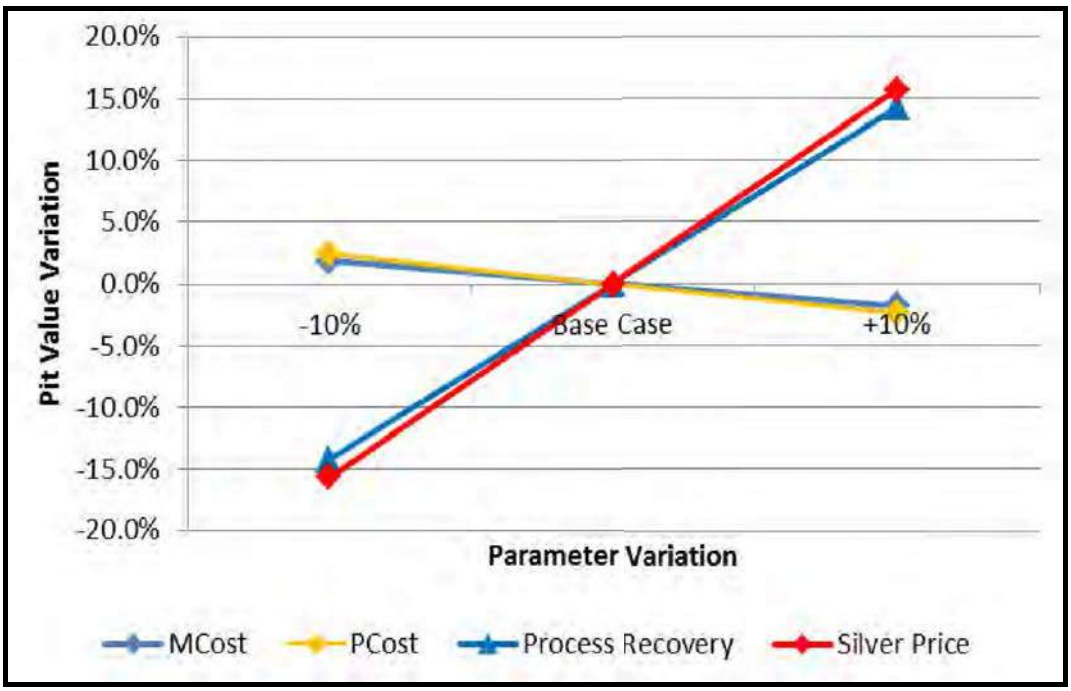
Sensitivity analyses were carried out on the pit operating value in the base case by varying the average mining cost, Pcost (process costs plus G&A costs), process recovery, and the silver price by ±10%. The results are presented in Figure 16.4 as a standard spider graph.

The effect of the mining and processing cost variation on the operating value of the selected pit shell is approximately 2.5%. However, a 10% change in the process recovery or silver price affects the undiscounted pit value by approximately 15%.

Higher process recovery and silver price result in an increase in the generated revenue; hence, the pit value is higher and vice versa.

The higher recoveries and metal prices result in a lower marginal cut-off grade; however, due to the grade distribution in the existing orebody the effect of the cut-off grade on the ore tonnage is negligible.

**Figure 16.4 Summary of Sensitivity Analyses on Pit Value**




### *Orebody Sensitivity to Cut-off Grade*

As discussed in Section 2.2, based on the selected parameters, the calculated marginal cut-off grade is approximately 240 g/t. A small cut-off grade variation shows a minimal effect on the overall tonnage in the North Pit, while the effect on the South Pit is negligible, if any. The grade-tonnage curves for the North and South pits are presented in Figure 16.5 and Figure 16.6.

The selected cut-off grade results in a better continuation of the orebody, allowing for a more selective mining possibility. This will improve the overall mining loss and dilution during the mining operation.

**Figure 16.5 Grade-Tonnage Curve for North Pit**

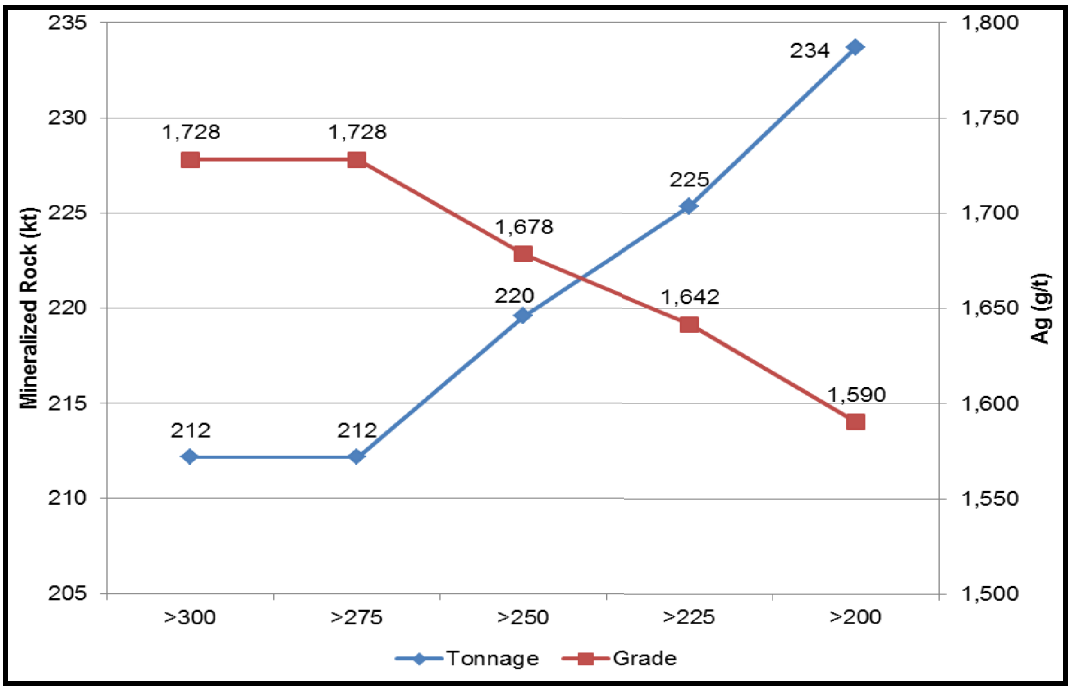
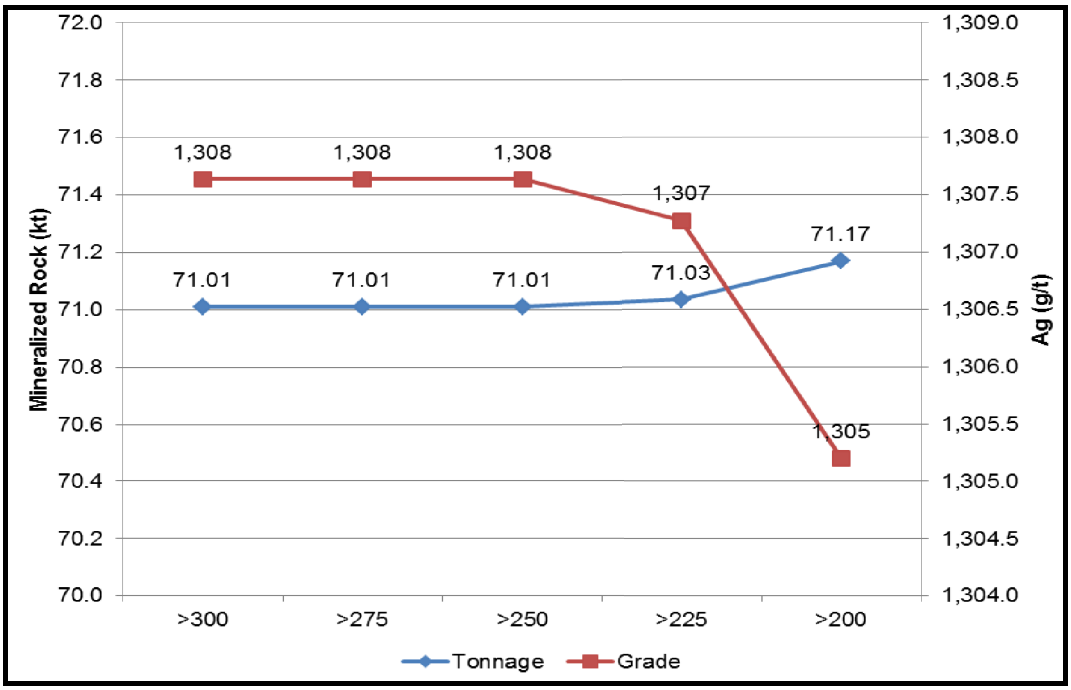



**Figure 16.6 Grade-Tonnage Curve for South Pit**



### 16.1.4 Open Pit Mine Design

GEOVIA GEMS™ software was used for the pit and WRD designs and for preparation of the end-of-period pit plans and rock inventory estimation.

The open pit consists of two separate pits; North and South pits, with separate access roads. The North Pit is designed in two phases where the Phase 1 Pit is inside the final North Pit and the South Pit is designed in one phase.

#### *Open Pit Design Parameters*

The basic open pit design parameters are determined by the geotechnical design criteria as set out by SRK (Appendix B) and the selected equipment for the mining operation. A summary of these parameters are provided in Table 16.3.

**Table 16.3 Pit Design Parameters**

| Parameter | Unit | Value |
|---|---|---|
| Bench Height | m | 10 |
| Face Angle | ° | 80 |
| Berm Width | m | 5.0 to 7.3 |
| North Pit Ramp Width | m | 10.0 to 16.0 |
| South Pit Ramp Width | m | 14.0 to 18.0 |
| Ramp Gradient | % | 10 |
| Minimum Working Width for Main Mining Areas | m | 15 |
| Minimum Working Width for Bottom/Final Benches | m | <10 |

#### *North Pit*

The North Pit was divided into two phases with the Phase 1 pit designed inside the final North Pit. A slot type ramping system is used as the main access to benches in the North Pit.

The North Pit design took into consideration the integration of the underground mine design by allowing pit benches and the internal ramping system to be used as an access to underground openings. In addition, the design aimed to provide:

- potential in-pit parking or service area for mining equipment
- areas within the pit to construct water collection sumps and pumping stations to prevent pit flooding
- temporary in-pit storage or mineral stockpile in the pit.

The two North Pit phases are shown in Figure 16.7 and Figure 16.8.

The Phase 1 pit is located at the northwest end of the final pit, with a total length of 490 m, maximum width of 105 m, and an overall height of 55 m. The pit exit, on the southeast side of the pit, is on the 1,166 m elevation and the pit bottom is on bench

1,130. A horizontal area of 50 m long and an average width of 25 m was designed on bench 1,145 to allow for a small sump or in-pit multi-purpose parking area.

The haul distance from the pit exit to the crusher is approximately 1,500 m at an average 3.5% gradient. The distance to the WRD and low-grade stockpile located adjacent to the WRD is 250 m. Temporary ramps could be used from various pit locations on the north wall to access both the crusher and the WRD to shorten the haul distances from the upper benches. Such roads should be considered during detail design by the mine planning engineer.

The Phase 2 pit (final pit) is an expansion of the Phase 1 pit, mainly towards the southeast direction. The North Pit is 860 m long and has a maximum width of 150 m. The pit bottom is in the northwest side of the pit on bench 1,085, resulting in an overall slope height of approximately 100 m.

The pit exit is on the 1,154 m elevation contour and in-pit ramp slopes down at 10% gradient to the bottom, only interrupted by a 65 m horizontal area on bench 1,105. The total ramp length excluding the horizontal portion is 500 m. The main ramp is 16 m wide to provide sufficient width for a two-way road traffic and working space during the mining operation. This selected width, in excess of the conventional 3.5 times truck width, is specified in acknowledgement of the unique slot-type ramp system with narrow working conditions when compared to a side hill ramp system where one side of the ramp is typically open allowing for easier excavation. In the final ramp sectors the ramp width is reduced to 10 m resulting in a slower mining operation in the final mining period.

An additional horizontal area is also designed on bench 1,135, next to the ramp, where part of the remaining ore vein could be extracted at the end of the open pit mine life.

Both horizontal areas (wider benches) could be used for water collection or in-pit parking areas, temporary storage, and equipment maintenance areas.

The road distance from the pit exit, located on the southeast side of the pit, to the crusher is approximately 1,900 m with an average 3.5% gradient. The haul distance from the pit exit to the WRD and low-grade stockpile is approximately 450 m. Similar to the Phase 1 pit, temporary ramps could be used to shorten the waste haulage distance from the upper benches. These ramps will be excavated when the pit progresses to the lower benches.

**Figure 16.7 Plan View of the Phase 1 Pit (North Pit)**

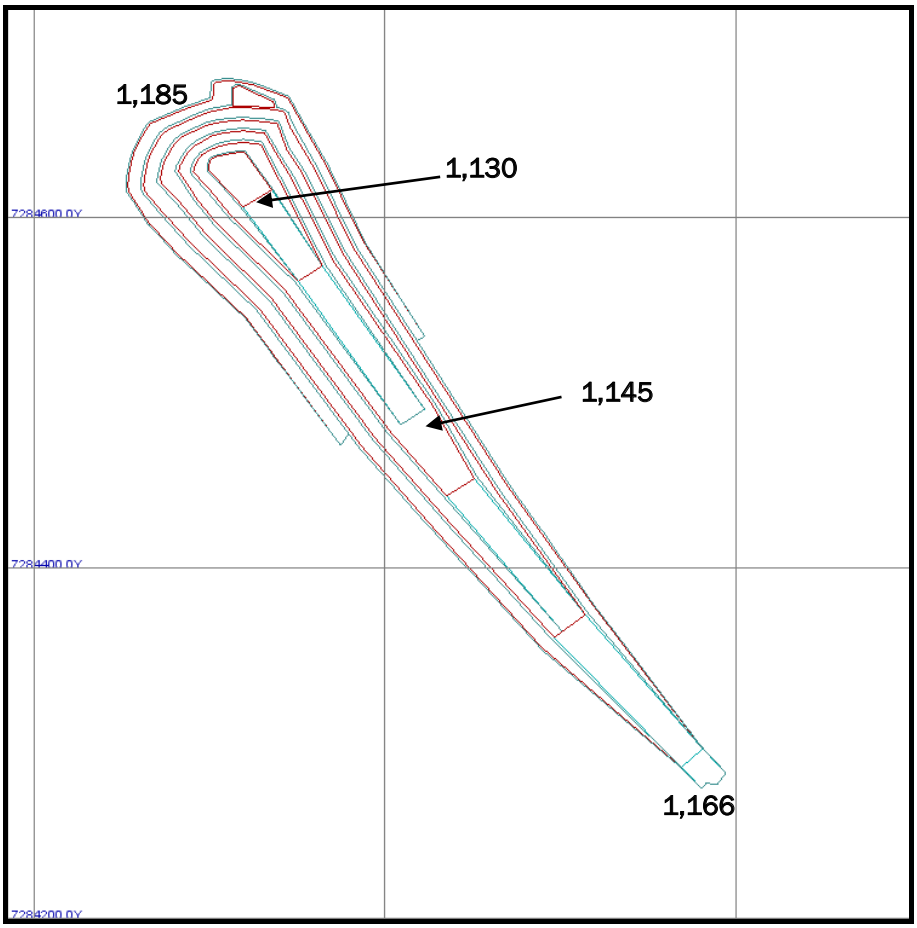
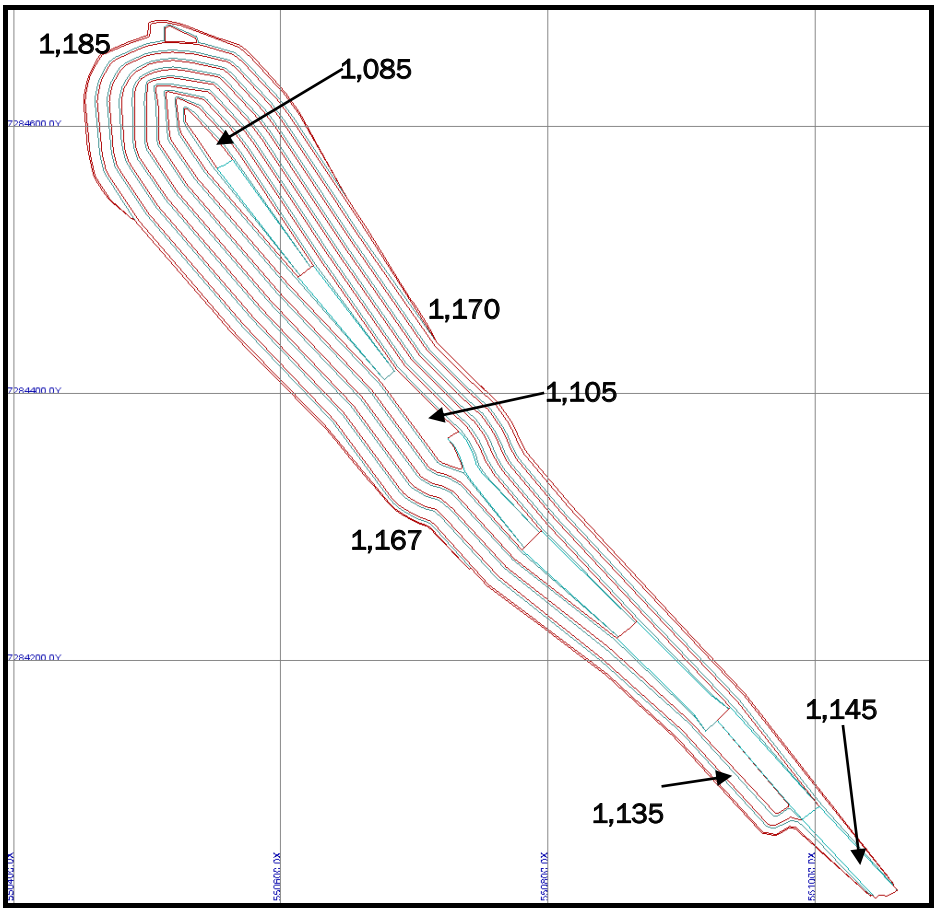


**Figure 16.8 Plan View of the Final Pit (North Pit)**




## 16.1.5 South Pit

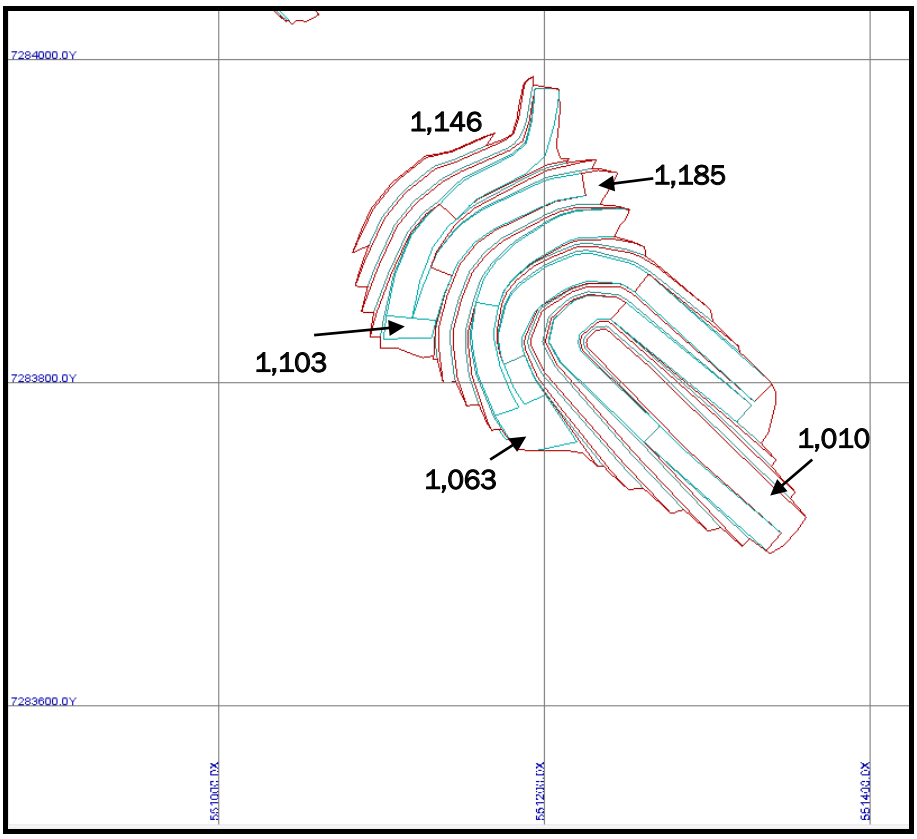
The South Pit, located southeast of the North Pit, is a side-hill pit with separate access road and an in-pit ramping system. The bench by bench access is provided by an in-pit spiral ramping system that, at the end of the open pit life, will be used as a portal to the underground mine (Figure 16.9). Access to the South Pit is from the 1,164 m elevation of the main crusher access road to the South Pit exit on elevation 1,120 m. The haul distance is 590 m at an average 7.5% gradient. Above the pit exit elevation, access could be provided using temporary ramps as an extension of the main road or an in-pit ramp. The same access road will be used to access the WRD and the low-grade stockpile.

The total length of the in-pit ramp is approximately 1,000 m, 300 m of which is above bench 1,090 and 700 m is the ramp from bench 1,080 to the pit bottom. Access for benches 1080 and 1090 is designed using an outside road at an approximate 9.0% gradient. The final ramp sector (1,020 to 1,010 m) is designed at 11% gradient. A backfill area is designed to extend the 1010 m pit bottom elevation to create working space and turning area at the end of the ramp.

The ramp width varies from 14 m on the sides of the pit to 18 m. This is to provide wider access in the areas where the underground portals will be designed and constructed, and to reduce the strip ratio on the sides.

The South Pit is 360 m long, 190 m wide, and the overall height of the northwest pit wall is 136 m.

**Figure 16.9 Plan View of the Final Pit (South Pit)**




### *Rock Inventories per Pit Phase/Area*

The in situ rock inventory per designed pit phases and areas is shown in Table 16.4. Total Mineral Reserve is calculated after applying mining dilution and losses to the in situ above cut-off grade mineral inventory inside the designed pits.

**Table 16.4 In Situ Rock Inventories in the Designed Pit Phases (September 2016)**

| Resource Classification | Grade Category (g/t) | Phase 1 | | Phase 2 | | South Pit | | Total | |
|---|---|---|---|---|---|---|---|---|---|
| | | kt | Ag g/t | kt | Ag g/t | kt | Ag g/t | kt | Ag g/t |
| Indicated | >240 | 82 | 1,622 | 139 | 1,696 | 71 | 1,308 | 292 | 1,581 |
| | <240 | 164 | 60 | 294 | 62 | 157 | 86 | 614 | 68 |
| Inferred | >240 | 2 | 514 | - | - | 1 | 504 | 2 | 512 |
| | <240 | - | - | - | - | - | - | - | - |
| Waste | - | 1,390 | - | 5,650 | - | 2,775 | - | 9,816 | - |
| **Total** | **-** | **1,638** | **-** | **6,083** | **-** | **3,004** | **-** | **10,725** | **-** |

Note: *Totals may not add due to rounding.

### *Waste Rock Dump and Low-grade Stockpile*

The WRD and low-grade stockpile are designed on the hill side, north of the North Pit. In this design, the stockpile is assumed to be on the shallower end of the designed dumping area, on the northwest side.

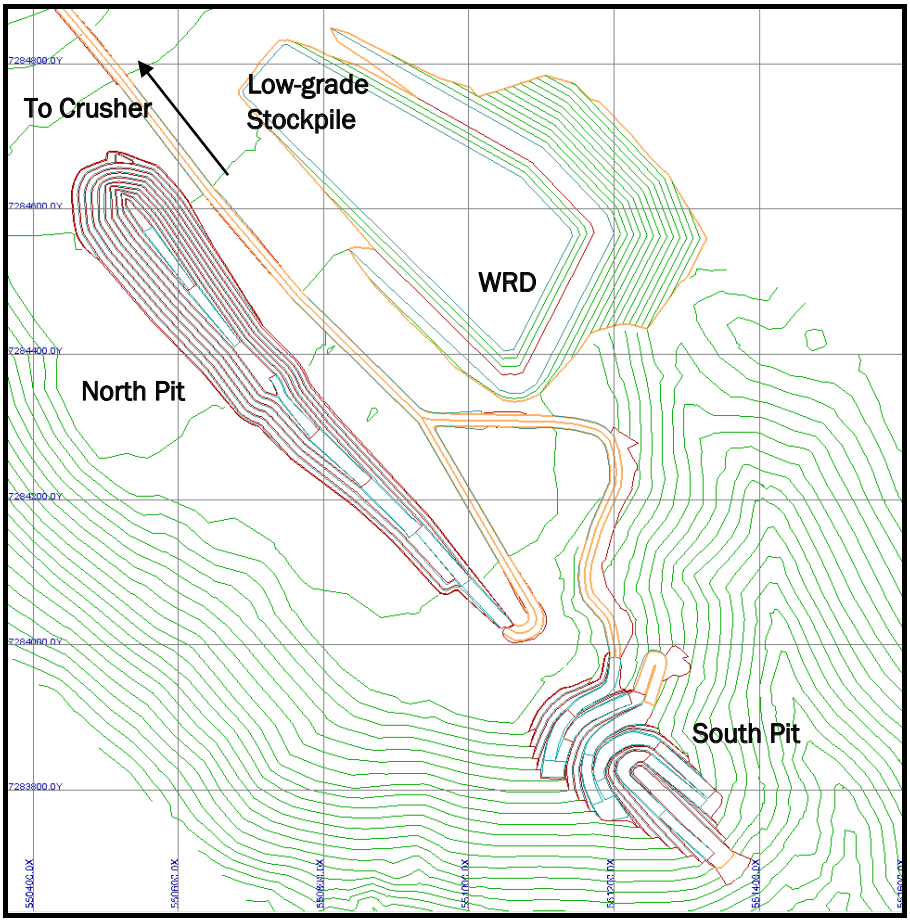
As a result of the natural topography the WRD height is less than 3 m on the northwest side, and gradually increases to approximately 30 m on the south end and 70 to 85 m on the north slope. The WRD is designed at a 25° slope angle with an overall dimension of 650 m in length and approximately 400 m in width.

It must be noted that the provided topography surface was somewhat short of covering the WRD area; therefore, the original surface was expanded for wider coverage. The actual topography may be different compared to the one used as the basis to design the WRD, due to the artificial expansion of the surface digital terrain model, but due to the sufficient space and the possibility to increase the WRD height, no issues are expected in expanding the WRD area.

The total design capacity of the WRD is 3.8 $Mm^3$.

The general layout of the designed pits, WRD, and low-grade stockpile, as well as the main haul roads are presented in Figure 16.10.

**Figure 16.10 General Layout of the Design Pits, Waste Dump and Haul Roads**



#### *HAUL ROADS*

The haul roads to the North and South pits are designed at a maximum of 10% gradient and 16 m width. The selected road width is more than the required 3.5 times the truck width (20 to 30 t trucks) for a safe two-way road traffic. This allows for flexibility during winter months for snow clearing. Road-side berms should be constructed with a height of 60% of the largest tire size of the deployed equipment for road safety reasons.

In preparation of the estimate the cut and fill volumes for the access road to the South Pit are estimated to balance the earthmoving requirement. The access road to the crusher is mainly a cut-and-grading operation, with some back filling in a few areas.

The presented road design in the general layout drawing (Figure 16.10) is mainly to show the road centre line and the projected road sides for access to the pits, WRD, and low-grade stockpile. A more detail design will be required for the construction stage.

### 16.1.6 OPEN PIT SCHEDULE

The open pit mining schedule was prepared assuming a mining operation start date of October 2016 to allow for the commencement of process plant production in January 2017. The presented schedule was prepared using the end of quarter pit plans for the first nine quarters, the end of 2019 pit plan, and the final pit for the last mining period in 2020.

The rock inventories were calculated using the end-of-period pit plans on a bench-by-bench basis and were used to prepare the monthly schedule after applying the mining dilution and losses to the ore tonnage.

Quarterly pit plans were prepared to show the approximate pit face position at the end of each period and to ensure availability of access to each bench and working area when the pit progresses to the next period. Some temporary ramps could be used to minimise the haul distance from the pit benches to WRD/low-grade stockpile and the crusher that will be excavated within the final pit phase. These are not shown in the pit plans.

In preparing the end of period pit plans, the aim was to maintain flexibility in selection of the ore and waste working faces, while exposing sufficient ore for excavation and delivery from the pit benches to the process plan in most periods. Providing access from one period to the following period was also a priority in preparing the plans. The mine planning engineer will be able to select the optimum working faces per period using the grade control results and the detail mining schedule that will be prepared on site.

During the pre-stripping period, sufficient ore is scheduled to be stockpiled for approximately 3.5 months of process plant production. While the stockpile will be available for use at any time, in this schedule, the use of the initial stockpile is limited to the periods where the grade of the ROM is lower than the stockpiled grade or during periods where, due to stripping requirements, limited ROM is available from the open pit. At the end of the open pit life, when the pit is depleted, the stockpile will

be utilised to maintain process plant production and to complement the underground ore tonnage destined for the process plant.

Tetra Tech notes that the use of the crusher stockpile in winter may be hampered by freezing. ZAO Prognoz advised that light blasting is regularly used in Russia to liberate frozen stockpile material. Although the use of stockpile in winter is minimised in this schedule, 40% of the process plant throughput is scheduled to be supplied from the stockpile in the Q1 2018. The crusher stockpile will be a live stockpile and could be depleted or grown, as required, even if in this schedule there are periods with no stockpile use.

At the start of the project the Resource was declared on the Russian State register at a cut-off grade of 75 g/t silver. Any material with a grade above this cut-off cannot be discarded as waste, which means that the 75 to 240 g/t silver material will be stored in a low-grade stockpile adjacent to the WRD. No dilution or losses are applied to this material. It is likely that during the mining operation some of the low-grade material will be diluted with the ore above the selected cut-off grade. The low-grade stockpile could also be used as a depository for the waste rock containing mineralised material as the mining loss. ARD is not expected from the WRD. Based on the selected economic parameters, this stockpile has no positive economic value and will not be used as a revenue generating material.

The mining schedule, the crusher stockpile movement, below cut-off grade stockpile inventory and the process plant production schedule for the open pit are presented in Table 16.5 and Figure 16.11. The scheduled benches per pit are shown in Table 16.6.

The total scheduled material to be hauled to the crusher is 364 kt at an average silver grade of 1,209 g/t. The total waste rock is 10.1 Mt and the low-grade material (75 to 240 g/t category) will be 218 kt at an average 115 g/t silver. No dilution or losses is applied to the low-grade material. The calculated overall strip ratio for this operation is 28.5.

The scheduled benches per period are presented in Table 16.5.

**Table 16.5 Open Pit Mining Operating, Stockpile Inventory, and Plant Production Schedule**

| Rock Type | Unit | 2016 | | | 2017 Q1 | | | 2017 Q2 | | | 2017 Q3 | | | 2017 Q4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Ore | kt | 7.3 | 9.0 | 13.7 | 6.0 | 7.0 | 11.4 | 10.6 | 9.2 | 2.7 | 7.6 | 7.0 | 6.2 | 9.2 | 7.3 | 9.17 |
| | g/t | 1,621 | 1,464 | 851 | 849 | 1,126 | 1,102 | 739 | 890 | 890 | 1,486 | 1,092 | 1,092 | 1,411 | 1,487 | 1,692 |
| Low-grade Stockpile | kt | 0.4 | 5.8 | 7.0 | 0.2 | 0.6 | 2.5 | 7.4 | 6.0 | 1.2 | 3.0 | 3.5 | 2.6 | 2.4 | 5.7 | 1.9 |
| | g/t | 78 | 111 | 150 | 117 | 131 | 133 | 147 | 123 | 123 | 103 | 118 | 118 | 117 | 120 | 112 |
| Waste | kt | 262.3 | 275.3 | 284.4 | 243.8 | 242.5 | 236.1 | 306.9 | 309.8 | 321.1 | 314.5 | 314.5 | 316.2 | 288.4 | 287.0 | 288.9 |
| Total | kt | 270.0 | 290.0 | 305.0 | 250.0 | 250.0 | 250.0 | 325.0 | 325.0 | 325.0 | 325.0 | 325.0 | 325.0 | 300.0 | 300.0 | 300.0 |
| Strip Ratio | | N/A | N/A | N/A | 40.7 | 35.0 | 20.9 | 29.6 | 34.5 | 118.2 | 41.9 | 45.4 | 51.5 | 31.7 | 40.1 | 31.7 |
| **Stockpile** | **Unit** | **2016** | | | **2017** | | | | | | | | | | | |
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Opening Balance | kt | | 7.3 | 16.2 | 29.9 | 29.9 | 29.9 | 33.3 | 34.8 | 34.8 | 28.4 | 26.8 | 24.6 | 21.6 | 21.6 | 19.8 |
| | g/t | | 1,621 | 1,534 | 1,222 | 1,222 | 1,222 | 1,210 | 1,066 | 982 | 899 | 881 | 852 | 852 | 852 | 852 |
| In | kt | 7.3 | 9.0 | 13.7 | | | 3.4 | 10.6 | 9.2 | 2.7 | | | | | | |
| | g/t | 1,621 | 1,464 | 851 | | | 1,102 | 739 | 890 | 890 | | | | | | |
| Out | kt | | | | | | | 9.2 | 9.2 | 9.2 | 1.6 | 2.2 | 3.0 | | 1.9 | |
| | g/t | | | | | | | 1,210 | 1,210 | 1,210 | 1,210 | 1,210 | 852 | | 852 | |
| Closing Balance | kt | | 16.2 | 29.9 | 29.9 | 29.9 | 33.3 | 34.8 | 34.8 | 28.3 | 26.8 | 24.6 | 21.6 | 21.6 | 19.8 | 19.8 |
| | g/t | | 1,534 | 1,222 | 1,222 | 1,222 | 1,210 | 1,066 | 982 | 899 | 881 | 852 | 852 | 852 | 852 | 852 |
| Low-grade Stockpile | kt | 0.4 | 6.2 | 13.2 | 13.3 | 13.9 | 16.4 | 23.9 | 29.9 | 31.1 | 34.0 | 37.5 | 40.1 | 42.6 | 48.3 | 50.2 |
| | g/t | 78 | 109 | 130 | 130 | 130 | 131 | 136 | 133 | 133 | 130 | 129 | 128 | 128 | 127 | 126 |
| **Plant** | **Unit** | **2016** | | | **2017** | | | | | | | | | | | |
| | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Open Pit | kt | | | | 6.0 | 7.0 | 8.0 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 |
| | g/t | | | | 849 | 1,126 | 1,102 | 1,210 | 1,210 | 1,210 | 1,438 | 1,120 | 1,014 | 1,411 | 1,359 | 1,692 |
| Underground | kt | | | | - | | | | - | | | | - | | | |
| | g/t | | | | | | | | | | | | | | | |

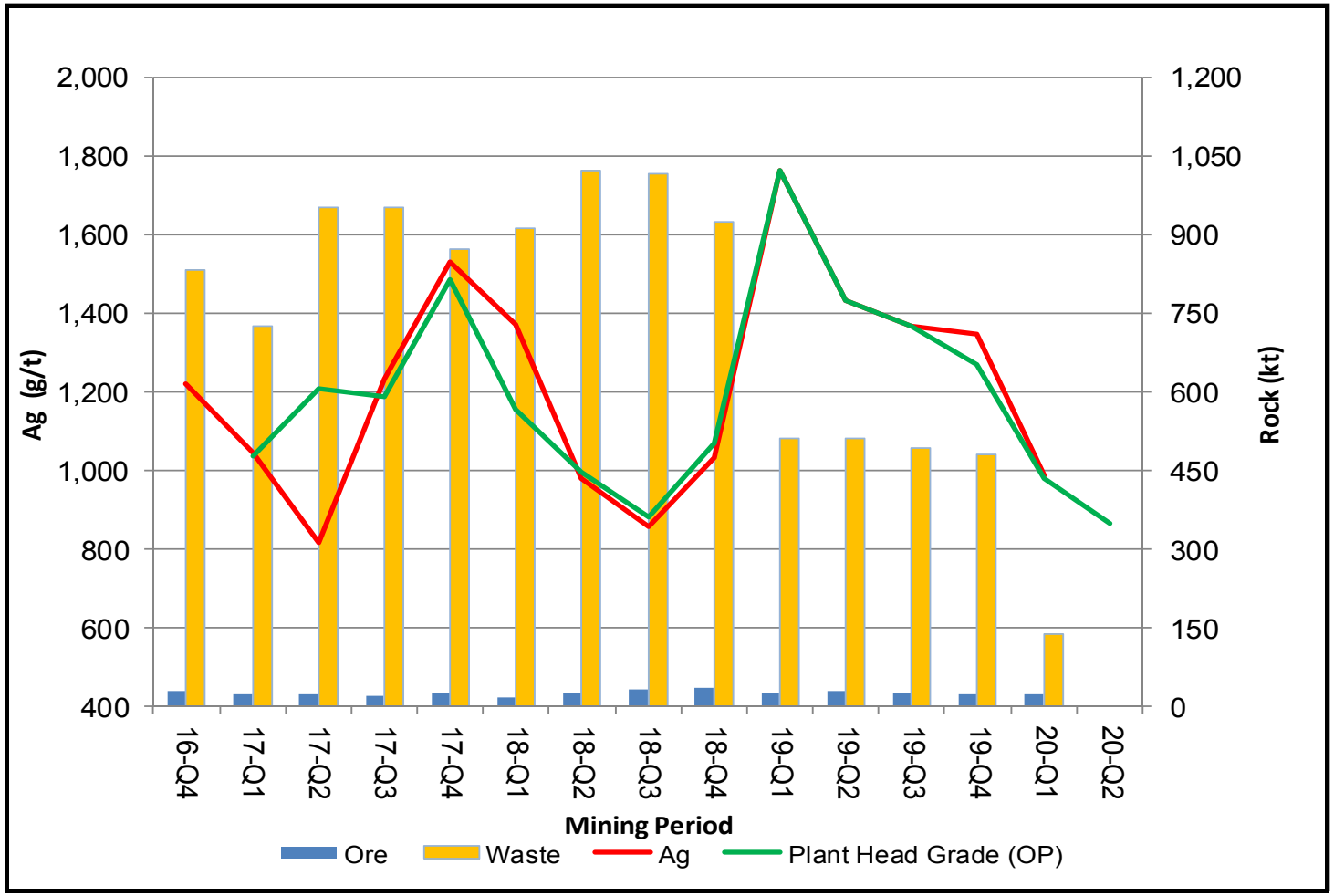
*table continues…*

| Rock Type | Unit | 2018 Q1 | | | 2018 Q2 | | | 2018 Q3 | | | 2018 Q4 | | | 2019 | | | | 2020 | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Ore | kt | 3.3 | 5.4 | 7.5 | 4.4 | 9.2 | 11.8 | 9.6 | 12.1 | 9.6 | 9.2 | 12.0 | 14.4 | 27.5 | 29.0 | 27.5 | 23.2 | 25.0 | - | 363.9 |
| | g/t | 1,033 | 1,115 | 1,707 | 1,000 | 915 | 1,027 | 696 | 811 | 1,075 | 1,128 | 1,084 | 934 | 1,763 | 1,436 | 1,367 | 1,347 | 991 | - | 1209 |
| Low-grade Stockpile | kt | 2.1 | 4.9 | 4.4 | 2.4 | 6.9 | 8.4 | 9.3 | 12.6 | 9.2 | 7.5 | 3.2 | 10.1 | 19.2 | 17.6 | 24.2 | 17.4 | 8.3 | - | 218 |
| | g/t | 115 | 123 | 104 | 111 | 124 | 117 | 85 | 94 | 113 | 136 | 131 | 120 | 101 | 111 | 117 | 121 | 105 | - | 115 |
| Waste | kt | 304.6 | 299.7 | 298.1 | 343.2 | 333.9 | 329.8 | 331.1 | 325.3 | 331.2 | 313.3 | 314.8 | 275.5 | 493.3 | 493.3 | 468.3 | 464.4 | 131.7 | - | 10,143 |
| Total | kt | 310.0 | 310.0 | 310.0 | 350.0 | 350.0 | 350.0 | 350.0 | 350.0 | 350.0 | 330.0 | 330.0 | 300.0 | 540.0 | 540.0 | 520.0 | 505.0 | 165.0 | - | 10,725 |
| Strip Ratio | | 92.8 | 56.7 | 40.5 | 79.3 | 37.2 | 28.6 | 35.4 | 27.8 | 35.4 | 35.0 | 26.6 | 19.8 | 18.6 | 17.6 | 17.9 | 20.8 | 5.6 | - | 28.5 |

| Stockpile | Unit | 2018 | | | | | | | | | | | | 2019 | | | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| Opening Balance | kt | 19.8 | 13.9 | 10.1 | 8.4 | 3.6 | 3.6 | 6.3 | 6.7 | 9.7 | 10.1 | 10.1 | 12.9 | 18.2 | 18.2 | 19.7 | 19.7 | 15.4 | 12.9 |
| | g/t | 852 | 852 | 852 | 852 | 852 | 852 | 742 | 739 | 744 | 747 | 747 | 790 | 818 | 818 | 866 | 866 | 866 | 866 |
| In | kt | | | | | | 2.7 | 0.4 | 3.0 | 0.4 | | 2.8 | 5.3 | | 1.5 | | | | |
| | g/t | | | | | | 592 | 696 | 754 | 816 | | 948 | 885 | | 1,436 | | | | |
| Out | kt | 5.9 | 3.8 | 1.7 | 4.8 | | | | | | | | | | | | 4.3 | 2.5 | |
| | g/t | 852 | 852 | 852 | 852 | | | | | | | | | | | | 866 | 866 | |
| Closing Balance | kt | 13.9 | 10.1 | 8.4 | 3.6 | 3.6 | 6.3 | 6.7 | 9.7 | 10.1 | 10.1 | 12.9 | 18.2 | 18.2 | 19.7 | 19.7 | 15.4 | 12.9 | 12.9 |
| | g/t | 852 | 852 | 852 | 852 | 852 | 742 | 739 | 744 | 747 | 747 | 790 | 818 | 818 | 866 | 866 | 866 | 866 | 866 |
| Low-grade Stockpile | kt | 52.2 | 57.2 | 61.6 | 64.0 | 70.9 | 79.3 | 88.5 | 101.1 | 110.3 | 117.7 | 121.0 | 131.0 | 150.3 | 167.9 | 192.1 | 209.5 | 217.8 | |
| | g/t | 126 | 126 | 124 | 124 | 124 | 123 | 119 | 116 | 116 | 117 | 117 | 117 | 115 | 115 | 115 | 116 | 115 | |

| Plant | Unit | 2018 | | | | | | | | | | | | 2019 | | | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| Open Pit | kt | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 9.17 | 27.50 | 27.50 | 27.50 | 27.50 | 27.50 | 12.93 |
| | g/t | 917 | 1,006 | 1,549 | 922 | 915 | 1,153 | 730 | 829 | 1,087 | 1,128 | 1,125 | 963 | 1,763 | 1,436 | 1,367 | 1,271 | 980 | 866 |
| Underground | kt | - | | | | - | | | | - | | | | | | | | | |
| | g/t | | | | | | | | | | | | | | | | | | |

**Figure 16.11 Open Pit Mining Schedule and Plant Head Grade from the Open Pit**



## Table 16.6 Scheduled Benches per Mining Periods

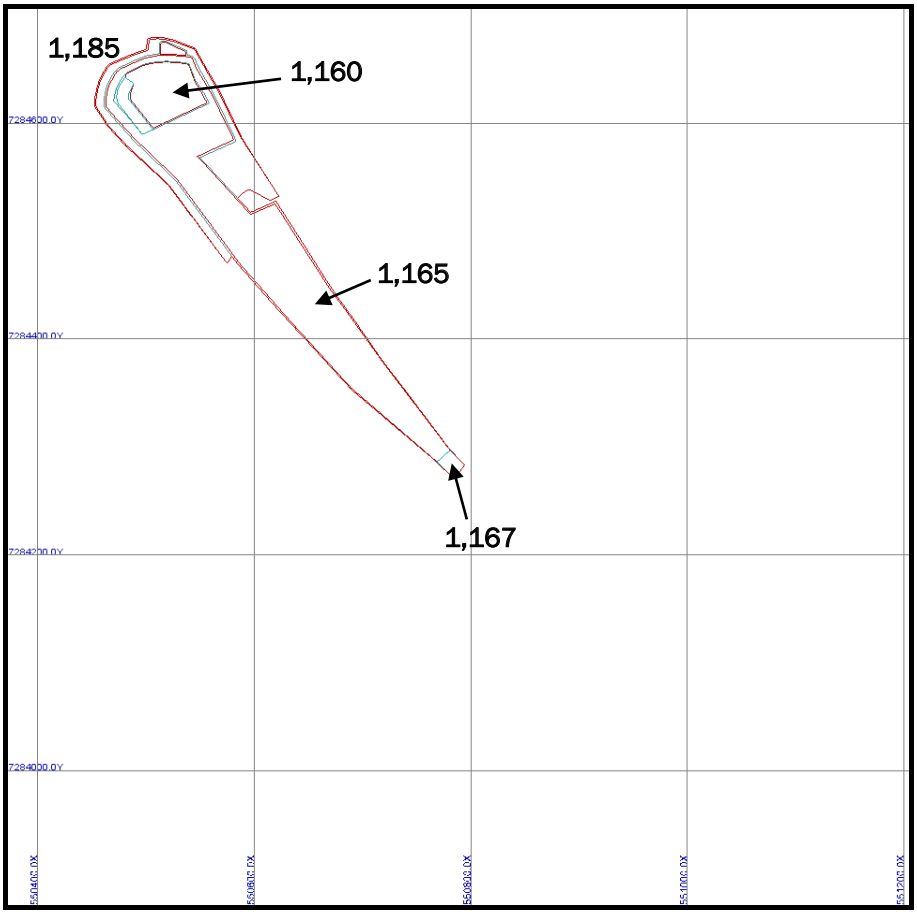
| | 2016 | | 2017 | | | | | | | | 2018 | | | | | | | | 2019 | | | | 2020 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q4 | | Q1 | | Q2 | | Q3 | | Q4 | | Q1 | | Q2 | | Q3 | | Q4 | | 1st Half | | 2nd Half | | | |
| Bench | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP | NP | SP |
| 1190 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1180 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1170 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1160 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1150 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1140 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1130 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1120 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1110 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1100 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1090 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1080 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1070 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1060 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1050 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1040 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1030 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1020 | | | | | | | | | | | | | | | | | | | | | | | | |
| 1010 | | | | | | | | | | | | | | | | | | | | | | | | |

Note: North Pit (NP); South Pit (SP)

### SCHEDULE TO THE END OF 2016

The pit plan for Q4 2016 was prepared for the pre-stripping operation, where approximately 30 kt of ore, at an average grade of 1,222 g/t, will be stockpiled at the crusher for future use. The low-grade material is 4 kt and 822 kt of waste will be excavated and hauled to the WRD. The total mined rock from the Phase 1 pit in this quarter is 865 kt. The approximate pit plan for the end of 2016 is presented in Figure 16.12.

**Figure 16.12 Approximate End of 2016 Pit Plan**




In this quarter, the mining operation is scheduled within the Phase 1 pit with mining three benches. The pit bottom is on bench 1160 in the northwest part of the pit.

It is assumed that construction of the main haul road, from the North pit to the crusher and WRD, will continue and be completed by the end of 2016.

Temporary ramps could be used to exit the pit from various locations to minimise the haul distances to the crusher or WRD/low-grade stockpile. These are not presented in the pit plan.

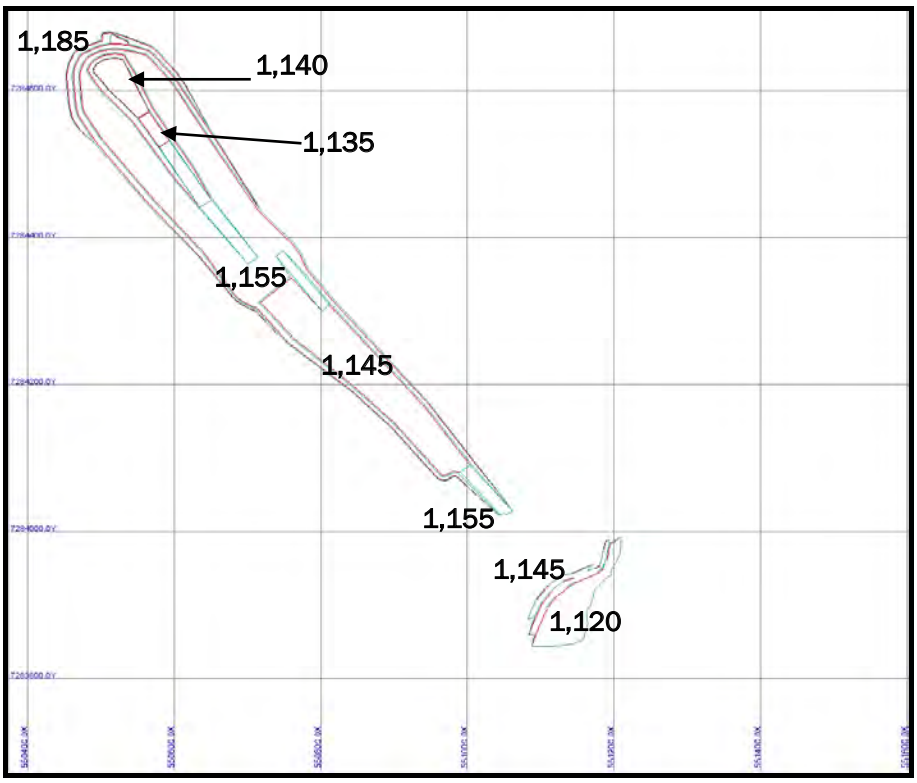
### SCHEDULE TO THE END OF 2017

The mining operation continues in the Phase 1 pit and gradually expands towards the final pit boundary. In this year the access road to the South Pit is scheduled to be

constructed and stripping of the upper benches above the 1,120 m elevation will be completed in the South Pit.

The end-of-year pit plan is presented in Figure 16.13 and the quarterly plans are shown in Appendix C.

**Figure 16.13 Approximate End of 2017 Pit Plan**




The pit bottom in the Phase 1 pit is on bench 1135 and the mined rock will be hauled using the designed in-pit ramp with a pit exit on 1,155 m elevation. Waste stripping will be carried out within the final pit on the hanging wall and footwall side of the Phase 1 pit as well as the southeast side of the North pit. At the end of the 2017, bench 1155 will be excavated to the final boundary and bench 1145 will be in operation.

Access to bench 1145 will be provided from the North pit exit in the southeast end of the pit and also via an in-pit ramp in the middle of the pit for temporary access to the crusher and WRD/low-grade stockpile.

In 2017, a total of 3.6 Mt of rock is scheduled to be removed from the North and South pits, where 93.3 kt is ROM material at an average silver grade of 1,167 g/t and the total waste and low-grade material is 3.5 Mt. In Q1 2017, 250 kt/mo of rock is scheduled to be removed, which will increase to 325 kt in the following six months. In the Q4 2017, the monthly rock tonnage is reduced to 300 kt. This configuration is due to the harsh winter conditions and the limited experience of the operation to such weather conditions. This could be modified by the site mining engineer, if necessary.

The process plant ramp-up schedule is assumed to be a three-month period, processing 21 kt (65%, 76%, and 87% of the nominal production rate of 110 kt/a) and in Q2 2017 the nominal plant production will reach 9.17 kt/mo.

Stockpile depletion is scheduled for Q2 2017. The relatively lower-grade ROM will be stockpiled and the higher-grade material from the stockpile will be utilised for process plant production. In Q2, 27.5 kt of stockpiled ore, at an average grade of 1,210 g/t silver, will be depleted and will be replaced by 22.5 kt of ore at an average silver grade of 819 g/t. The depletion of the stockpile continues in Q3 at a lower rate, to complement the ROM to maximise the process plant nominal rate. Minimal stockpile tonnage is utilised in Q4 2017 and most of the process plant feed is scheduled from the open pit. At the end of 2017, 20 kt of ore, at an average 852 g/t silver, will remain in the stockpile.

It could be observed in the quarterly plans that access to each bench is maintained and the waste stripping is scheduled so that the ore is exposed ahead of the mining operation in the following period.

In 2017, due to the available number of benches and mainly wide mining areas, the schedule is very flexible for selecting the waste stripping working faces as long as it is within the end of the year pit plan.

#### *Schedule to the End of Open Pit Mining*

Detail on the interim pit plans are provided in Appendix C.

### 16.1.7 Open Pit Mine Operations

#### *Operational Approach*

A conventional load-and-haul mining method is planned for the open pit, using relatively smaller equipment to produce 110 kt/a of ore and to carry out the waste stripping. The mine operation, including maintenance and technical services, will be run by ZAO Prognoz.

Due to the harsh winter weather conditions, personal and equipment fatigue will be a major factor for the safety of the mining operation. Tetra Tech expects relatively higher mechanical fatigue of the mining equipment resulting in higher maintenance costs and lower mechanical availability when compared to an operation in a warmer weather condition.

Strict personal safety rules should be implemented to minimise the risk of the operation during winter.

It must be noted that, owing to the variable vein thickness, there will be areas with a narrower vein width than the excavator resulting in higher than average dilution. This is offset in thicker sections of the orebody where the converse is true.

In order to minimise the dilution and mining losses during the mining operating, the following methods could be deployed:

- approach the orebody from hanging wall front

- limit the ore production to day shift
- light the ore loading face at the night shift
- use smaller buckets for loading ore material
- accurate grade control
- clearly mark the contact between ore and waste in the pit.

A detailed estimation of the dilution was not carried out in this study.

### *Mine Equipment Requirements*

A summary of the estimated fleet requirement to achieve the LOM plan is presented in Table 16.7 and the details are provided in Appendix C. The fleet estimates for drilling, loading, and hauling equipment was carried out using the developed mining schedule, a similar drill and blast pattern as per SRK (Tetra Tech 2016), approximate annual haul distances to the crusher and WRD, number of working faces per period, and the estimated work regime and mechanical availability and utilisation factors.

The ancillary equipment were estimated based on previous experience on similar projects and approximate required hours for the Project.

**Table 16.7 Required Equipment Summary**

| Equipment | Type | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| Truck | 20 t | 7 | 10 | 10 | 10 | 7 |
| Backhoe | CAT336 | 2 | 3 | 3 | 3 | 2 |
| Drills | Atlas Copco T40 | 3 | 3 | 3 | 2 | 1 |
| Track Dozer | CATD9 | 1 | 1 | 1 | 1 | - |
| | CATD8 | 2 | 3 | 3 | 3 | 2 |
| Grader | 14M | 1 | 2 | 2 | 2 | 2 |
| Water Cart | - | 2 | 2 | 2 | 2 | 2 |
| Service Truck | - | 1 | 1 | 1 | 1 | 1 |
| Fuel Truck | - | 1 | 1 | 1 | 1 | 1 |
| Lowbed Truck | - | 1 | 1 | 1 | 1 | 1 |
| ANFO Truck | - | 1 | 1 | 1 | 1 | 1 |
| Loader | CAT930 | 1 | 1 | 1 | 1 | 1 |
| Pickup Truck | - | 10 | 10 | 10 | 10 | 10 |
| Lighting Units | - | 4 | 4 | 4 | 4 | 2 |

There is available equipment currently on site, as per Table 16.8.

Mining equipment should be utilised with arctic condition packages and the diesel must be winter-grade fuel for the cold months.

**Table 16.8 Summary of the Existing Mining Equipment On Site**

| Equipment | Type | Number On site for Mining |
|---|---|---|
| Truck | 20 t | 4 |
| Track Dozer | CAT D9R | 1 |
| Backhoe | CAT336 | 1 |
| Loader | CAT950 | 1 |
| Water truck | 6 $m^3$ | 1 |
| Fuel truck | 8 $m^3$ | 1 |

### *Shift Roster*

The selected work regime for the mining operation amounts to 330 operating days and two, 12 hour shifts per day. This results in a total of 7,920 hours in a year. The lower operating days take into account operation stoppage due to extreme weather conditions.

The technical services staff will be on a one shift schedule.

Details of the shift roster, the work regime, and utilised hours per year for the mining equipment are presented in Appendix C.

### *Drilling*

The selected blasthole diameter for this operation is 76 mm and the drilling pattern in ore will be 1.90 m by 2.10 m and in waste rock will be 2.20 m by 2.50 m. The drill-and-blast will be carried out in 10-m benches. The total blasthole length including sub-drilling will be 11.0 m. The yield for each blast-hole will be approximately 124 t in ore and 165 t in waste rock. In the estimates, 10% additional drilling is allocated to secondary blasting and control blasting operations.

The selected drill for this operation is an Atlas Copco SmartROC T40 downhole drilling machine, with a drilling diameter range of 76 to 127 mm. This machine is flexible and is equipped with an air conditioned cabin for an all year around operator comfort and is suitable for winter operation.

Three drilling units will be required until the end of 2018 and then with the reduction in the total rock movement in 2019, two drills will provide the required drilling capacity until the end of the mine life. The third drill will remain on site as a backup drilling machine in case one of the units breaks down. The estimated equipment hours and the required units are presented in Appendix C.

It is assumed that grade control will be carried out using the collected samples from blasthole drills muck pile. Separate calculations for grade control drilling requirements were not carried out in this study.

### *Blasting*

Currently, a blasting contractor is carrying out the blasting operation on site. However, with the commencement of the mining operation a dedicated blasting crew

employed by the mine will be responsible for the blasting operation. Ammonium nitrate/fuel oil (ANFO) and water resistant explosives (if required) will be used for blasting. It is expected that most of the holes will be relatively dry or only partially wet. The ANFO will be prepared in an on-site plant.

An explosives magazine and an ANFO mixing plant will be available on site to prepare and store the explosives and the blasting accessories.

The annual explosives requirements were determined based on estimated powder factors of 0.26 kg/t and 0.21 kg/t for ore and waste rock, respectively. The powder factors have been calculated for this study and are presented in Appendix C. In addition, a 5% allowance was used in the estimates for a secondary and control blasting operation. The blasting requirements are presented in Appendix C.

Trim and control blasting techniques could be used for the following purposes:

- selective blasting in ore vein
- minimising potential damages to the pit wall due to back breaks
- maximising bench face angles and therefore the overall slope angle
- lowering the risk of fly rock.

The safe blasting distance to the administrative buildings, fuel tank, and other sensitive infrastructure is usually 500 m (local by-laws should be used for this purpose). During the blasting operation, as part of the safety procedures, all administrative and mine operational personnel should be evacuated to a safe distance of not less than 500 m to a covered and secure location. The mining equipment should also be moved to a safe distance from the blast.

#### *LOADING*

Backhoe excavators are the most suitable loading equipment that could be used in this open pit mining operation. The flexibility of the backhoe units for selective mining of the blasted orebody, and the manoeuvrability in small working spaces, are a few of the advantages of this loading equipment.

A backhoe excavator with a 1.9 $m^3$ bucket capacity is already in operation on site. The smaller bucket size will be suitable for selective ore excavation. Due to the low ore production rate, this excavator will also be utilised in the waste stripping operation. The larger bucket size (2.4 $m^3$) backhoe units will be dedicated to waste stripping. The recommended units are equivalent to CAT 360 backhoe excavator models.

The existing front-end-loader on site will be utilised as a secondary loading unit, mainly for depleting the crusher stockpile. If needed, it could be used in the waste stripping operation in case of a temporary breakdown of one of the excavators.

Based on a 90% bucket fill factor, and 30% and 35% swell factors, the bucket capacity is calculated at 4.7 t and 3.9 t for waste and ore rock types, respectively. The loading unit productivity per year is calculated using an availability of 81%, utilisation factor of 70%, and loading efficiency factor of 80 to 90%. Accordingly, the average production capacity for the 2.4 $m^3$ capacity unit is 1.5 Mt/a and 0.9 Mt/a for

the smaller bucket size. In total, two larger bucket size backhoe excavators, and the existing 1.9 $m^3$ bucket excavator will be sufficient to carry out the loading operation.

It must be noted that in addition to the loading capacity of these units, the number of loading faces in the North and South pits are factors used in estimating the required number of loading units in each year.

The details of the excavator requirement estimates are presented in Appendix C.

### *HAULING*

The required dump trucks were estimated by using 20-t trucks and the estimated average annual haul distances per year for ore and waste rock. The average speed for each sector of the road was also estimated and used in the truck cycle time calculation. Using the calculated cycle time, the annual truck productivity was then estimated and accordingly the required trucks for each period were determined.

Larger trucks with 30-t capacity will be a mismatch with the selected smaller size backhoe excavator buckets due to longer loading cycle time, lower excavator productivity due to longer idle time to receive the next truck, and the allocation of the number of trucks to each loading station.

Due to weather conditions, and the fact about the lower mechanical availability of the trucks that are manufactured in Belarus, and to allocate a relatively optimal number of trucks per loading equipment, ten trucks are required in years 2017 to 2019. In the quarterly periods in 2016 and 2020, seven trucks will provide sufficient capacity to maintain the annual production.

The details for the required truck estimation are provided in Appendix C.

### *ANCILLARY EQUIPMENT*

The major ancillary equipment requirements (dozers, graders, water trucks, secondary loader, service truck) were estimated based on the total annual rock movement, number of loading and dumping stations, rough assumptions regarding earthmoving requirements, regular road maintenance, and snow removal.

A number of ancillary equipment such as an excavator, 20-t trucks, track dozer, a road grader, and front-end-loader are already in operation for road building and other earthmoving operations at site.

Deploying a sufficient number of dozers will result in the following operational improvements:

- increase in dozing capacity on the WRD
- allocation of one dozer per excavator, and improved scheduling of the remaining dozing capacity for road maintenance and WRD
- better maintenance of bench and WRD working surfaces
- clearing and levelling the loading area resulting in an increase in shovel productivity

- improvements on the travelling surface on each bench, and therefore an increase in truck travel speed and lower tire repair and maintenance cost
- improvement in the long-term maintenance cost of the load and haul fleet.

Utilising the smaller size track-dozers will complement the existing larger dozer to achieve the optimum dozing capacity and allow the larger dozer to be utilised in road building activities in 2017 and 2018.

The road maintenance will be carried out by two CAT14M road graders together with two, 20 kl capacity water carts. Utilising larger water carts would reduce the number of filling times; however, it is understood that smaller size models are already in use on site. The use of water carts in above freezing condition is crucial to minimise the road dust; however, during the freezing temperatures there will be minimal or no use for this equipment.

Fuel trucks will mainly be used for re-fuelling the in-pit loading and dozing equipment.

A low-bed truck would be useful for transportation of the dozers and the backhoe excavators for distances greater than 500 m.

A service truck with a fuel and lube compartment could be used for the in-pit maintenance and small repair operation.

The available loading equipment on site could be used as a secondary loading equipment in the pit in case of a breakdown of backhoe excavators and in utilising the stockpile. It could also be used to transport heavier items such as equipment tires, sump pumps, and other items that would fit in the bucket or on the utility handler attachment.

Pickup trucks, lighting units and sump pumps will also be required for the operation.

## 16.2 UNDERGROUND MINING

### 16.2.1 UNDERGROUND MINING METHOD SELECTION

An analysis of the mining methods available to exploit a narrow vane, steeply dipping ore body such as the Vertikalny deposit identified two main contenders, namely sub-level open stoping and shrinkage stoping. Tetra Tech selected sub-level open stoping as it offers the most favourable outcome in the three key areas of safety, cost, and dilution. Drawbacks of the labour intensive shrinkage stoping include:

- Shrinkage stoping leaves too much high-value, broken ore in the stopes for extended periods.
- Shrinkage stoping is a low ore productivity operation, which requires numerous stoping areas to be developed simultaneously to meet the production demand and to provide sufficient ore contingencies to smooth out mine production. As a result the development requirements increase significantly when compared to sub-level open stoping.

- Because it requires more people working multiple areas to work at the face, shrinkage stoping exposed miners to rock falls when mining the voids and considered less safe than mechanised sub-level open stoping.
- Shrinkage stoping is a manual, labour intensive mining method, with relatively poor productivity factors and lower operating efficiencies.
- Shrinkage stoping is a very expensive exploitation method, especially for low-production operations, due to the labour requirements and the number of operators required on a two-shift-per-day roster. This effect is exasperated on a remote mine where personnel carry a high G&A cost.
- Planning mechanised loading and hauling with labour intensive stoping methods has always proven problematic. It requires that the stoping mechanisation is coordinated with the loading and hauling strategy to fully realise the benefit of improved mining technology and increase productivity.

It is concluded that the recommended underground mining method for Vertikalny is mechanised sub-level open stoping, with remote stope loading, and the recommended sequence of stope extraction is retreat-top-down mining, with adequate in situ rock pillars left unmined for localised and regional stability.

### 16.2.2 Optimisation

Numerous underground stope optimisation runs were performed using Datamine MSO software to develop stope shapes for various minimum mining widths and vertical level spacings. The MSO analyses concluded that a 25-m vertical-level spacing, with a top and bottom ore drive yielding an effective 22-m vertical stope drilling height, is appropriate for the Vertikalny deposit. The high-grade mineralisation envelopes were modelled with surrounding lower grade mineralisation and, when targeting stope shapes within higher grade mineralisation, it is possible to have portions of the low-grade mineralisation as part of the planned mining dilution.

Mining loss factors were applied to simulate the possible blockages that could occur with very narrow planned stopes. Accurate small diameter blasthole drilling, together with an adequate powder factor and accurate blast initiation, should mitigate the risks of stope blockages.

### 16.2.3 Geotechnical Characterisation

SRK prepared an open pit and underground geotechnical study in support of the feasibility study (Appendix B). It was noted that the ground conditions are generally good with no special measures required for orebody extraction.

The updated underground mine design also considered the recommended hydraulic radiuses as documented in (Appendix B).

### 16.2.4 Hydrological and Hydrogeological Characterisation

SRK specified and supervised a hydrogeological site investigation to:

- achieve sufficient understanding of the hydrogeology of the proposed mine and assess the dewatering requirements

- quantify and assess the availability of the groundwater storage in the sub-permafrost aquifer to supply the required amount of water to the Project.

The following conclusions were drawn from the site investigations and data analysis (Appendix K):

- Both the open pit and underground mines will be entirely located in the permafrost; therefore, groundwater inflow into the mine workings, if any, will be negligible.
- Surface water runoff during the summer months (May to September) remains the main inflow component that requires active management, especially during exceptional storm events. For average conditions during this period, the required pumping capacity to manage surface water runoff is approximately 100 $m^3/h$; however, for exceptional storm events (100-year return period) the required pumping capacity is 200 $m^3/h$. During freezing conditions (October to April) surface water is frozen and precipitation falls in the form of snow; runoff does not occur.

### 16.2.5 Underground Mine Design

#### *Mine Layout*

The underground mine will consist of two distinct mining areas: the North Zone and South Zone. As there is no advantage to connect the two mining areas, each zone will have its own independent access decline system. Ramp accesses were selected for both underground mining zones, taking into account the stopes' proximity to the bottom of the planned open pits and the need to provide for operational flexibility through multiple mining areas and accesses. The South Zone design includes adit access for the upper mining levels from within the South pit, linked to the deeper mining levels with a South Zone ramp system. The South Zone ramp system is necessary to provide adequate ingress and egress opportunities and for ventilation control purposes. Each zone has its own ventilation districts.

Figure 16.14 depicts the underground mine layout designed for Vertikalny.

Sub-level open stoping is typically described as in-ore development with retreat long-hole open stoping extraction. The ore drives, slot raises, and stoping blocks (in-ore excavations) are accessed by a waste decline system located close to the orebody; however, not too close, as there are risks such as blast shock vibrations and excavation interaction stresses that could impact the integrity of the main access development drives if they are located too close to each other.

Figure 16.15 depicts the access option for the South mine. South mine's access consist of a series of in-pit adits with ore drives that ultimately link up to the South mine decline system. The advantage of in-pit access is the shorter distance to the underground mineable resources and to a centralised position from where the decline system can be developed.

**Figure 16.14 General Underground Mine Design Layout**

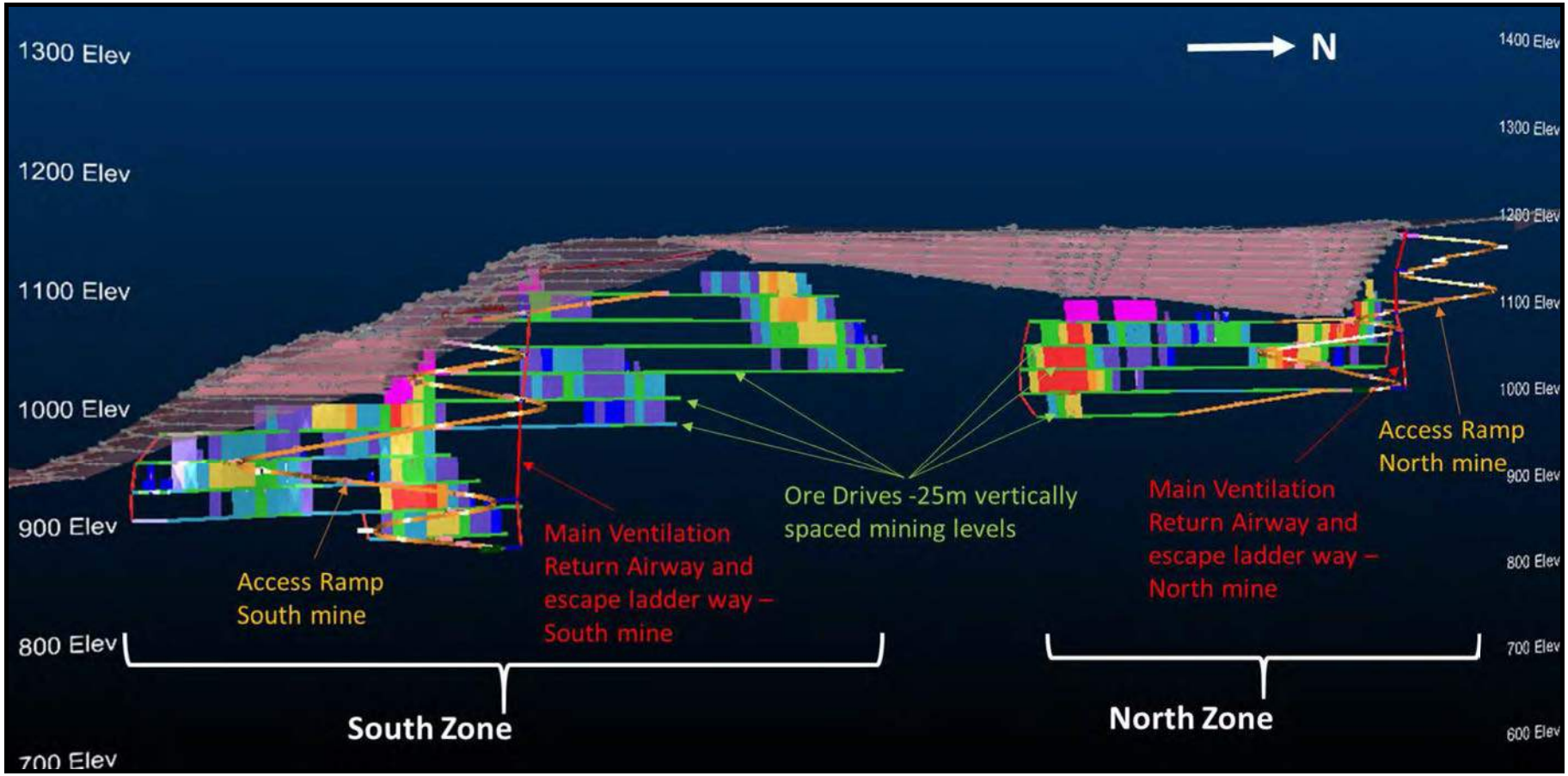
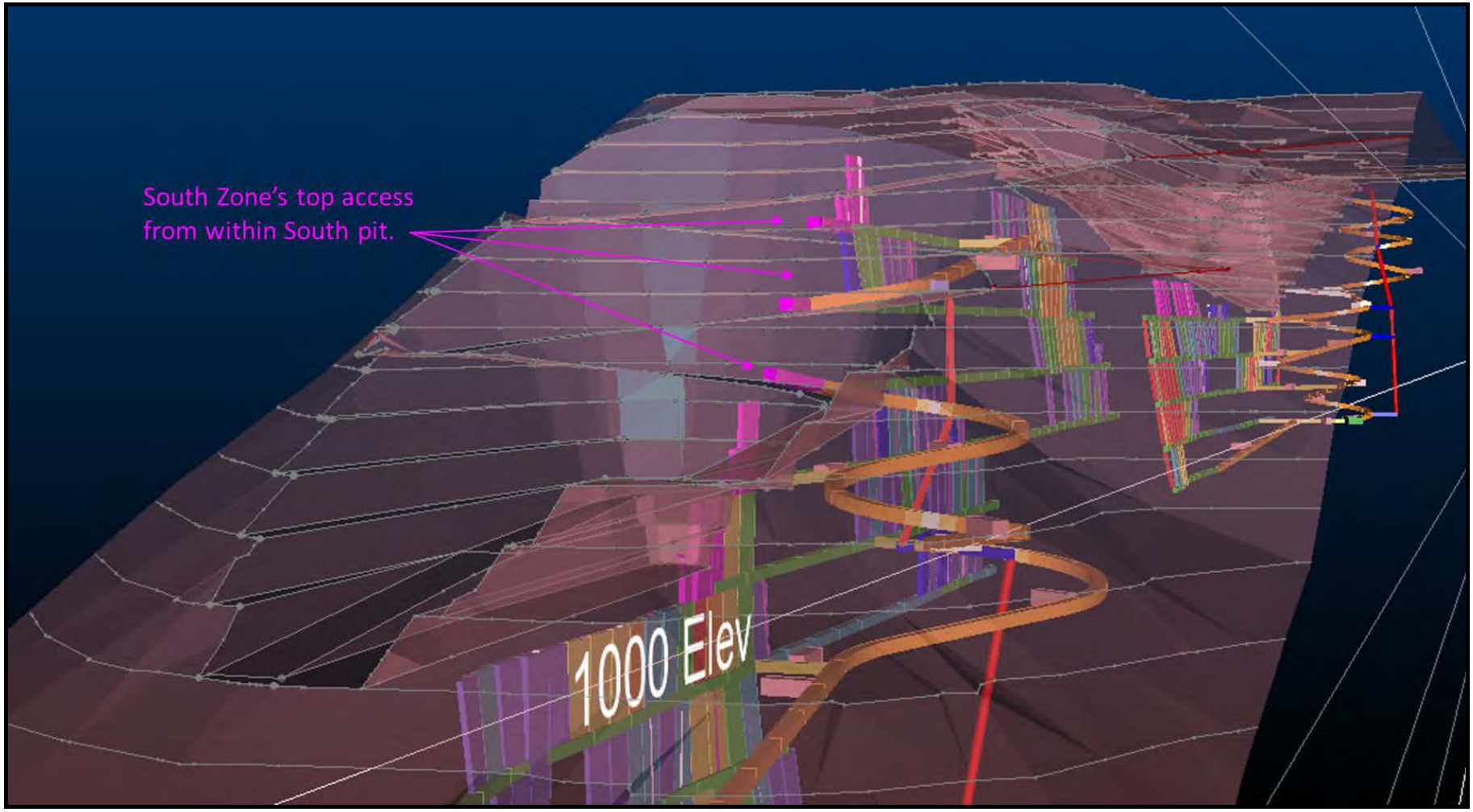


**Figure 16.15 South Zone Top-level Access**



## DEVELOPMENT AND PRODUCTION SCHEDULE

### Access Availability

Considering that underground access ramps and adits are tied into the open pit designs, the timing of their development is contingent on the open pit mining schedule. Underground mine development is planned to commence six months prior to the conclusion of the open pit operations to ensure continuous ore feed to the mill, and it will be further five months before the first stope will be ready for production.

The production ramp-up period for Vertikalny is assumed to take around 15 months, at which time 9.2 kt/mo of ore will be consistently produced from the underground operation. The underground ore will be stockpiled due to variations in ore production rates, owing in large part to variations in stoping widths and the linear development advance rate restrictions imposed.

### Development Rates

Based on Tetra Tech's experience, a maximum development rate of 145 m/mo (in a single heading) was applied to main development headings. The overall development rate was limited to 295 m/mo, based on the estimated productivity of the development equipment (single boom jumbo and load-haul-dump (LHD)) and the peripheral activities such as grade control in ore drives, support, and service installations. It should take the production crews approximately six months to ramp-up to 250 linear meters per month of overall mine development due to the time it takes to establish sufficient development headings (which is essential for maximum utilisation of the single boom jumbo drill).

### Stope Production

Each 25 m high by 10 m strike length stope was designed together with each stope slot raise. The slot raise was used to link activities to the stope activities and each stope rate was calculated based on the time it would take to prepare the stope, develop a stope plan from a grade control block model, to drill the stope long holes, and to blast the stope.

The slot raises will be developed prior to the actual stoping operations (well in advance of stoping commencement) to allow for clearing of slot raises that may be blocked because of poor drilling and blasting achievements and to allow for through-ventilation. Some slot raises may also be equipped with a simple chain ladder should they be considered as temporary escape ways. Ore activities leading up to a typical stope depletion include:

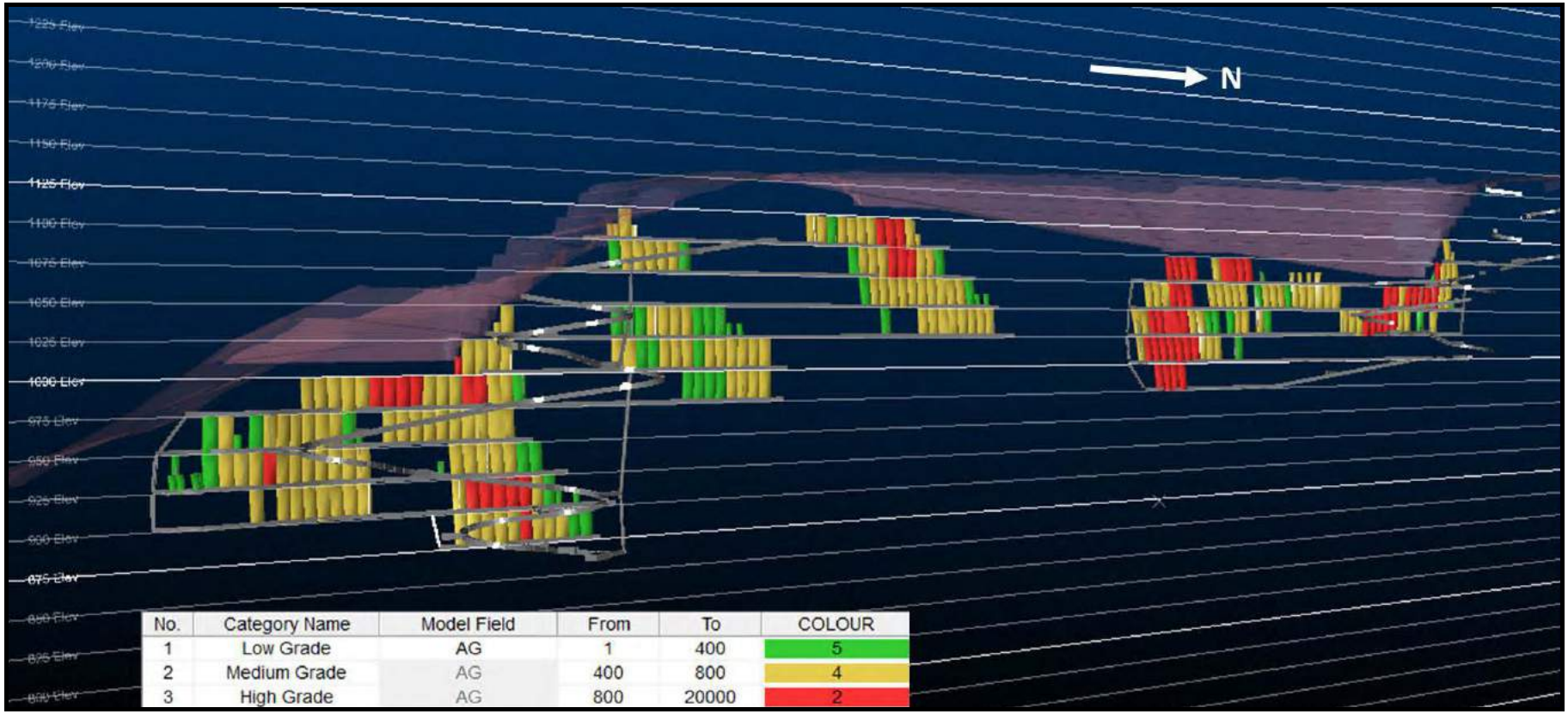
- Ore drives will be developed (3 m wide by 3.2 m high).
- Slot raises will be developed 2 m from the end of each planned mining stope (1.5 m wide by 1.5 m high)
- Drilling and blasting of slots may be done from either the top (downholes) or the bottom (upholes). From experience, clearing of holes when drilling upholes are more efficient and require less re-drilling. There may be the need to drill upholes and downholes in some stopes where stoping widths of less than 1.6 m are planned. Drilling from both sides could potentially

reduce the mining dilution, while allowing improved drilling accuracy, especially where the mineralisation poses undulating geometric challenges.

- Stope production rates of 240 t/d will be scheduled (once the stope is ready and available for extraction).
- The typical stope drilling time required will be three hours or less. The slot raises for each stope contain eight blastholes, and will be drilled in approximately 2.5 hours. The slot raises and the stope blastholes will be drilled sufficiently in advance, prior to a stope being blasted.
- Stope blastholes will only be charged (filled with explosives) a day or two prior to the stope being fired (the explosives standing time in the stopes will therefore be reduced as practically possible).
- Extraction factors will be applied to each stope:
  - Crown pillar stopes (stopes located near the crown pillars below the planned open pits) have a 90% extraction factor applied with a further 5% mining loss.
  - The remainder of the stopes have a 95% extraction factor applied with a 5% mining loss.
- A monthly production target of 9,160 t/mo has been set for scheduling purposes.

Figure 16.16 depicts the designed stopes coloured by grade bin.

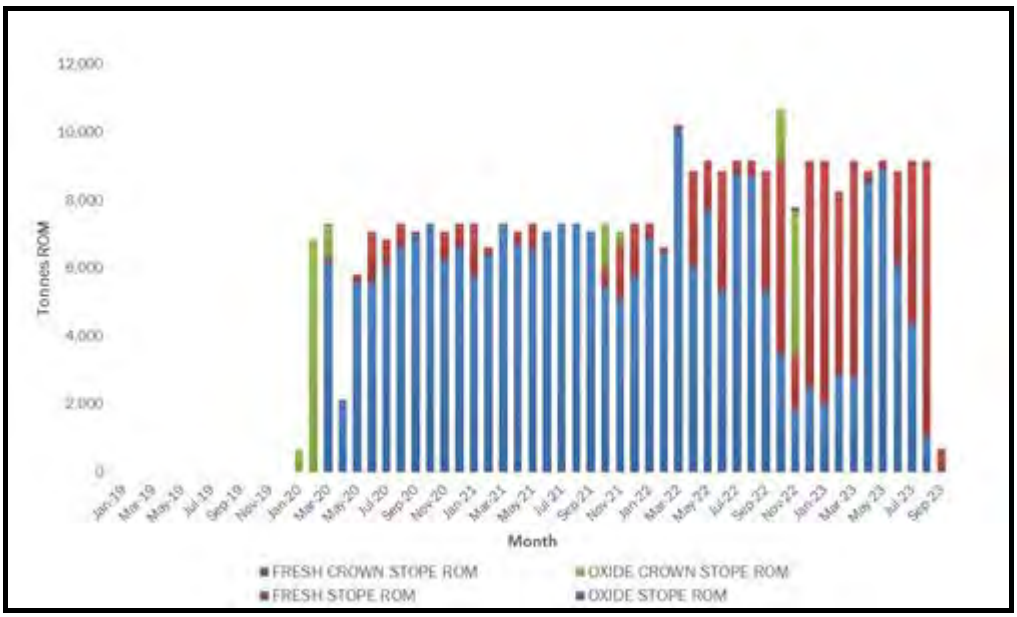
**Figure 16.16 Stope Grade Profile (Planned Stopes)**



Some smaller stopes are visible; these will be drilled with upholes from the bottom access ore drive.

While stope optimisation was completed in Datamine MSO, the underground designs, sequencing, and production scheduling was developed using Datamine Studio 5D Planner and EPS software.

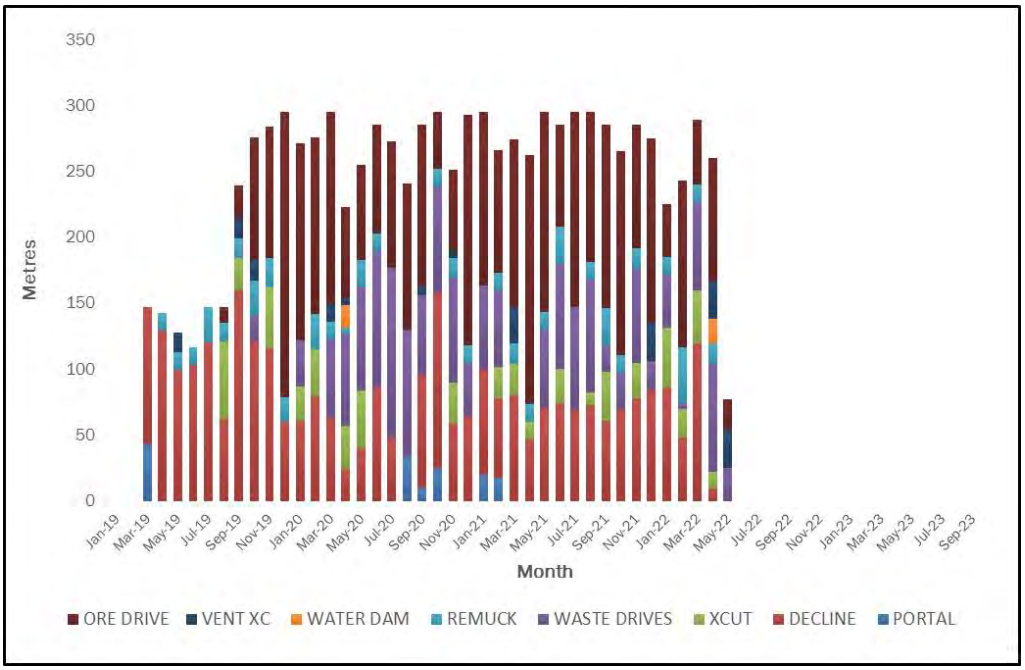
**Figure 16.17 Stope ROM Production Profile (Schedule)**




### *Development Schedule*

Figure 16.18 depicts the lateral waste development schedule for the proposed underground workings. Waste rock will be sent to the WRD. Development and production schedule rates for the North and South zones take into account material handling and technical management logistics, such as length of ore and waste rock haulage routes, equipment cycle times drill area preparation and oredrive grade control. Due to the overlap between open pit and underground operations at the start of underground development, the blasting schedule for both open pit and underground operations should be adapted to suit shift change. Re-entry periods will be dictated by the blast size and ventilation in the affected areas.

**Figure 16.18 Underground Mine Development Schedule**




## 16.2.6 UNDERGROUND MINE SERVICES

### *ELECTRICAL RETICULATION*

The underground mining equipment, and therefore underground service requirements, were calculated based on the production schedule developed for Vertikalny.

Underground power will be generated on surface by a diesel generator located either near the main decline portal of North Zone where a bulk of the initial mining will take place, or strategically located using the minimum electric cabling lengths. A back-up generator will service both mining zones. It is highly unlikely that two generators will be non-functional at the same time; therefore one back-up generator should suffice for the entire Vertikalny underground mine. The North Zone will be fully developed before the South Zone development commences and stoping will only commence in the South Zone once the North Zone is depleted. This allows the strategic planning of services, the potential to reclaim services from the North Zone, and to install some of these services in the South Zone. Underground mine planning includes basic

As the underground mine is fully mechanised, strategically placed electrical sub-stations, which provide power to all headings, are necessary within 500m of any mine heading. An electrical substation will be located on each mining level. Electrical substations can be moved or relocated once a mining level is depleted. This can be scheduled during night shift with switch over scheduled at strategic shift changes.

Power points will be located no further than 80m from active drill headings as the cable reels for the single boom jumbo drills will be limited to 100m. Power points for the single boom jumbo drills will be three phase points, with 60KW rating.

services for every development meter designed; cost calculations assume new services everywhere in the underground mine.

### *Mine Ventilation*

Ventilation requirements were calculated taking into consideration the simulations concluded in the previous feasibility study (Tetra Tech 2016).Total air volume is calculated as 72 $m^3/s$, should the following equipment all be running continuously in the same mining section:

- one jumbo
- one development LHD
- one production LHD
- one development truck
- one production truck
- one long hole.

When considering the maximum ventilation flow and the average ventilation requirements, it is deemed acceptable to allow for a 60% continuous equipment utilisation (multi-fleet or equipment scenarios). This also assumes that the equipment will be running full throttle, which is unlikely for the road grader, service vehicles, and light vehicles.

An airflow of 45 $m^3/s$ is the result of using a 0.6 factor on the whole fleet. Primary flow designs will be based upon a 56 to 58 $m^3/s$ delivery system (Table 16.9).

**Table 16.9 Ventilation Flow Requirements**

| Diesel Fleet Equipment | Engine Size (kW) | No. of Equipment Running Simultaneously | Air Requirements Without Multi-unit Factor ($m^3/s$) | Air Requirement With Multi-unit Factor ($m^3/s$) |
|---|---|---|---|---|
| Jumbo | 55 | 1 | 6 | 4 |
| Development LHD | 90 | 1 | 10 | 6 |
| Production LHD | 90 | 1 | 10 | 6 |
| Development Truck | 175 | 1 | 19 | 12 |
| Production Truck | 175 | 1 | 19 | 12 |
| Long Hole | 73 | 1 | 8 | 5 |
| Grader | 90 | 0 | 0 | 0 |
| Service Vehicles | 70 | 0 | 0 | 0 |
| Light Vehicles | 68 | 0 | 0 | 0 |
| **Total** | - | - | **72** | **45** |

The light vehicles, service vehicles, and motor grader were not included in the ventilation calculation as these vehicles should not consistently operate underground during full-production tramming hours. The motor grader may only be used when the haul trucks are being re-fuelled and light vehicles will be parked in a re-muck bay when other equipment runs in the declines.

### *Ventilation Fans*

A total of eight, 55 kW fan units will be in full operation at any one time for total power consumption. There will likely be 10 to 11, 55 kW fans installed, but to allow 45 $m^3/s$ of air through a maximum airway pressure system of 10,000 Pa, 8 fans running at almost full capacity will be required. Therefore, the ventilation power requirements include eight, 55 kW fans running at approximately 80% efficiency.

The cost of ventilation ducting was included as part of the underground mine operating costs and additional secondary 55 kW fans to boost the airflow were also included in the underground mine operating costs under air installed costs.

### *WATER SUPPLY AND PUMPING*

Given the depth of permafrost at the Project, Tetra Tech expects the underground mine to be dry with negligible ground water ingress, however, this will be confirmed with continuous water studies at Vertikalny. For this Feasibility Study, Tetra Tech assumed that water will be reticulated to the mine in a typical 4-inch or 100-mm diameter polyvinyl chloride (PVC) pipe. This will feed a collection sump underground that has a float valve. The collection sump will be situated at the lowest adit of each of the discrete "mines" and will receive water from the levels above via ramps, raises, and drain holes. The stopes will also convey water downwards. The gradients of the underground development will generally facilitate drainage from the mine towards the adits to avoid flooding, but all excess water will be routed to the collection sumps. The underground mine is expected to be a major consumer of water, with limited discharge to the environment. A key point to note—the local laws regarding heating the mine air to 2°C do not apply during permafrost conditions. Therefore, an alternative approach must be taken with the mine water supply to prevent regelation. The incoming water supply pipe should be insulated and salt added upon discharge at the sump. This is a common approach adopted in Russia in these kinds of conditions where underground heating is not used.

Each collection sump is planned to consist of a 10-m long excavation, 10 $m^2$ in cross section. Dirty water will flow into the sumps for primary settling before cascading over a wall into the sump where the pump will be situated. The supply will be conveyed to the working areas in 100 mm HDPE pipes suspended on the sidewalls of the drives. Water supply for the stopes will utilise 100 mm diameter HDPE pipes reducing to 50 mm rubber pipes for the drills. The key uses of water anticipated for the underground operation are summarised in Table 16.10.

**Table 16.10 Water Usage Calculations**

| Unit | Water Usage (l/min) | Water Usage (l/h) | Drilling (h/d) | Water (l/d) | Water ($m^3/d$) |
|---|---|---|---|---|---|
| Jumbo T1D | 45 | 2,700 | 14 | 37,800 | 37.8 |
| Long Hole Drill Rig | 50 | 3,000 | 14 | 42,000 | 42.0 |
| Watering Ore | | | | 25,000 | 25.0 |

Water consumption for watering down ore post blasting is estimated at 8% of ROM production. Water content will need to be carefully controlled to reduce the risk of ore freezing during the winter months.

The data in Table 16.10 are at steady state, assuming full production with one jumbo development drill rig and one long-hole drill rig in operation.

Water usage and salt addition will need to be monitored carefully during operations to prevent the build-up of ice in the workings.

During the summer months approximately 60% of the service water could potentially be re-used depending on the extent of the underground workings. The ground conditions and rock temperature will dictate the overall water balance.

### 16.2.7 Mine Development Schedule

The following underground development excavations were designed to provide main access to the Mineral Resource:

- decline (main access)
- remuck bays (where rock will be re-handled from LHD to haul trucks
- waste access drives (drives from the decline to the ore access drives (ore drives)
- ventilation drives (these are ventilation tunnels connecting the main access drives to the ventilation hole top and bottom holing positions)
- ore drives (these are in ore tunnels/excavations along the strike of the mineralisation zone, giving drilling access for slot raise and stope drilling and loading)
- slot raises are vertical excavations developed from the bottom ore drives (within each stope). These raises are developed to provide a free breaking face during stope blasting and to act as a temporary ventilation raise and escape way (a link between the sub-levels).
- water sump excavations (tunnels developed wherein a large water sump will be established)
- short ventilation holes (drilled by the long hole drill rig) and drop-raised
- longer ventilation holes were scheduled and costed to be developed by raise boring contractors.

All ventilation holes will have a strong polyester escape ladders installed with the steps folded down to reduce air resistance. They can be deployed if these ventilation raises are needed as escape ways.

Figure 16.19 and Figure 16.20 summarise the development end sizes for the Vertikalny underground mine.

**Figure 16.19 Development Sizes**

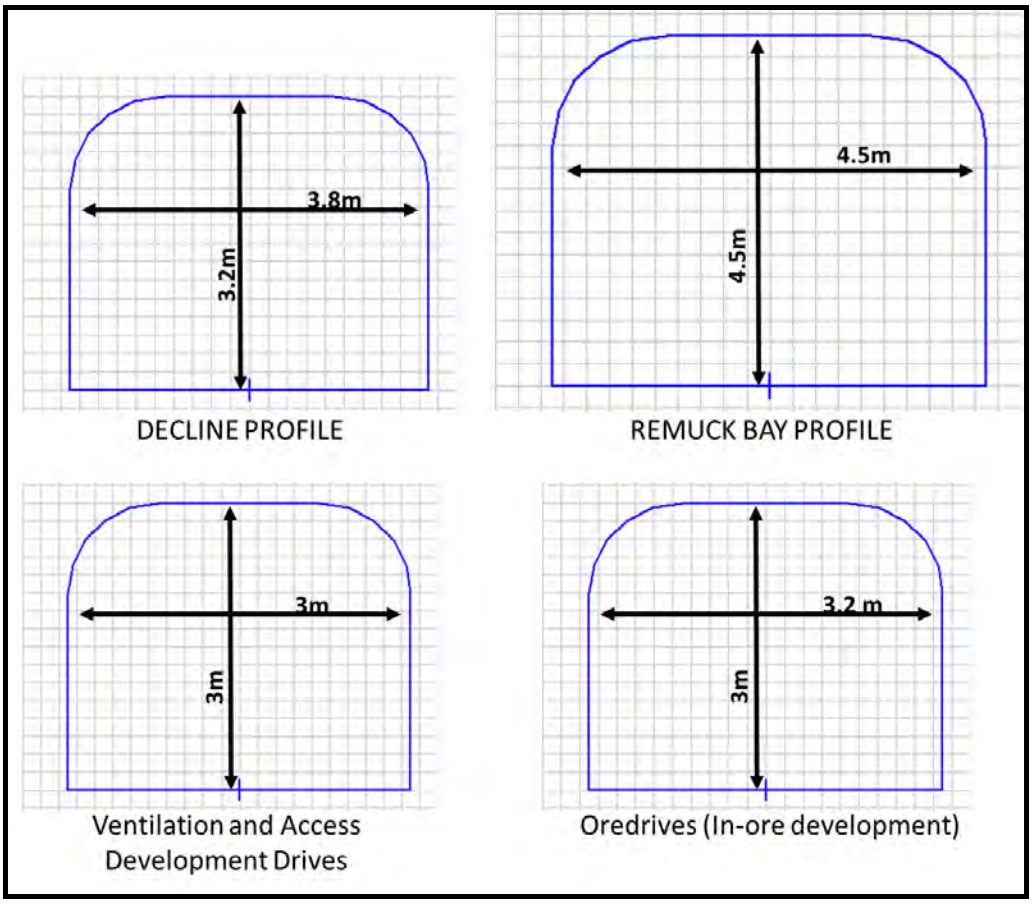
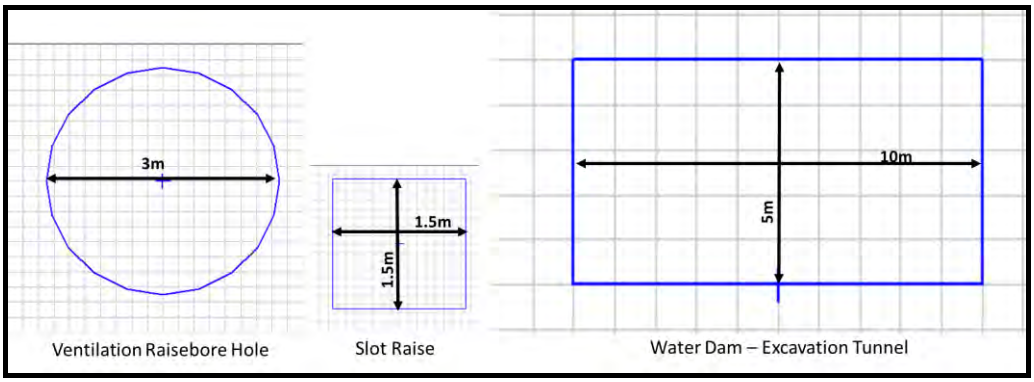



**Figure 16.20 Other Excavation Sizes**




The development drive end sizes considered the small mining equipment considered for development activities. The following figures illustrate the equipment sizes:

**Figure 16.21 Single Boom Jumbo Drill Rig for Development Drilling**

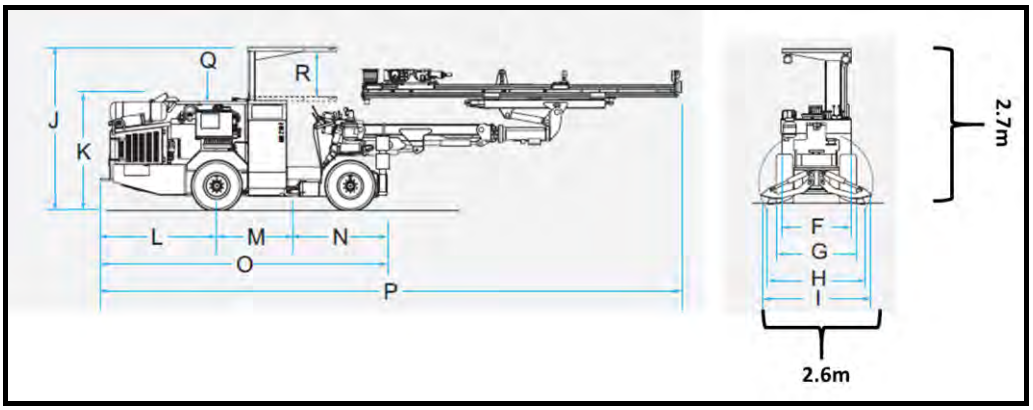
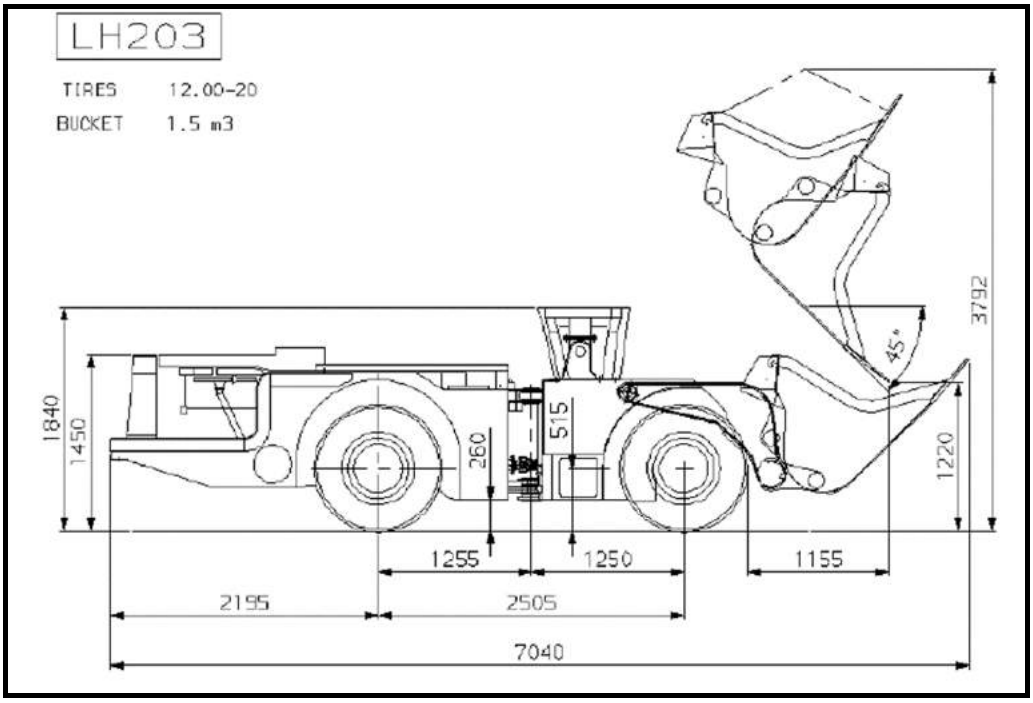


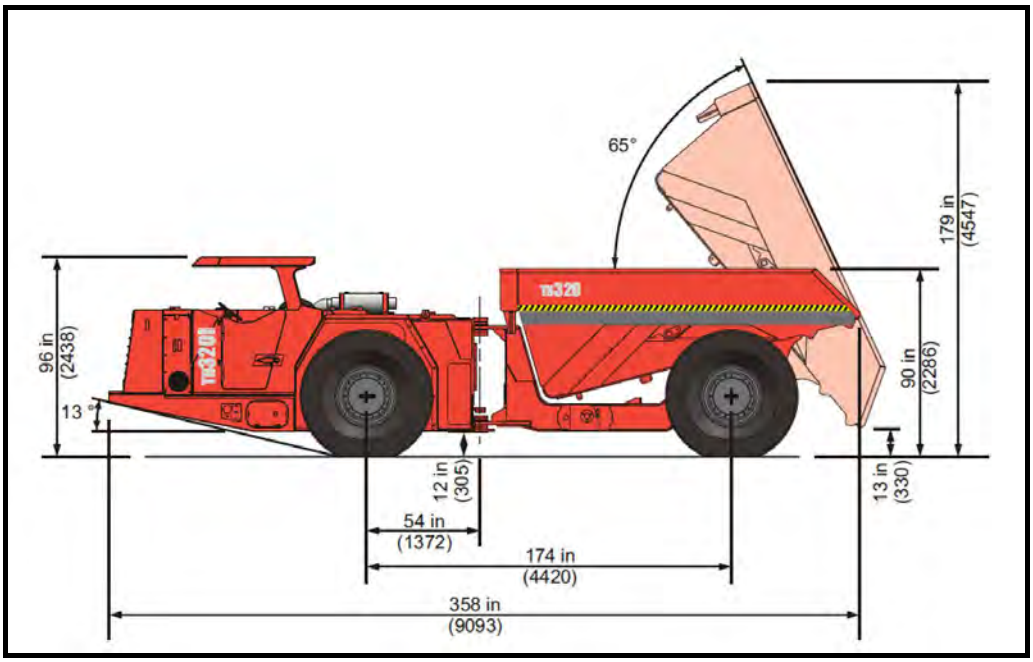

**Figure 16.22 Typical LHD Equipment Size Specification Considered**




The LHD will only dump rock into haul trucks in the re-muck bays, where the height of excavation is 4.5 m. The width of the LHD is typically 1.5 m.

Vertikalny may likely use 17- or 20-t haul trucks for the underground operations. Tetra Tech considered the development heading sizes that are able to accommodate a 20-t haul truck (Figure 16.23).

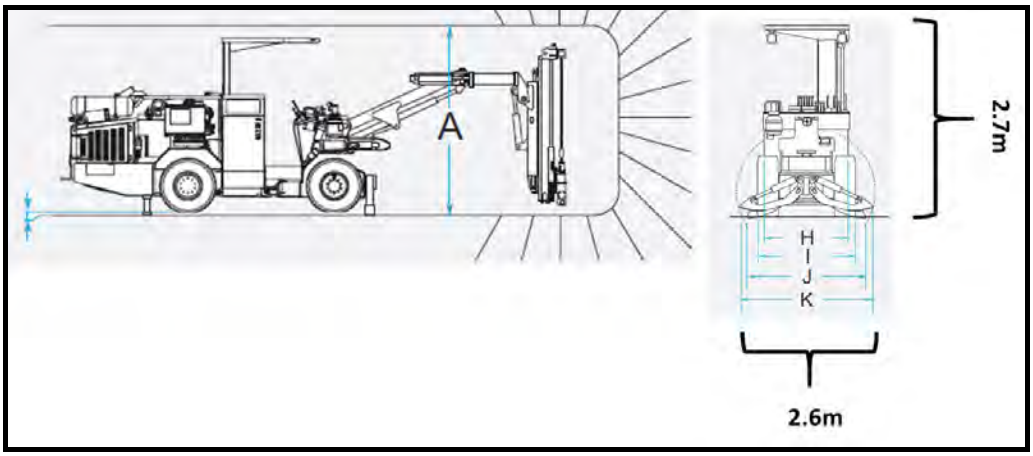
**Figure 16.23 20-t Underground Mining Truck Dimensions Considered**




The equipment sizes presented does not necessarily reflect Tetra Tech's equipment recommendations. The equipment available in the Tetra tech mining database was used to illustrate typical size specifications.

The ore drive size dimensions were increased (compared to Tetra Tech (2016)) which is necessary to allow for a small long hole stope drill rig (Figure 16.24).

**Figure 16.24 Long Hole Drill Rig (Typical Dimensions)**




Tetra Tech does not necessarily recommend any specific equipment brand. The equipment figures depict dimensions considered when designing the excavation sizes for the Vertikalny underground mine.

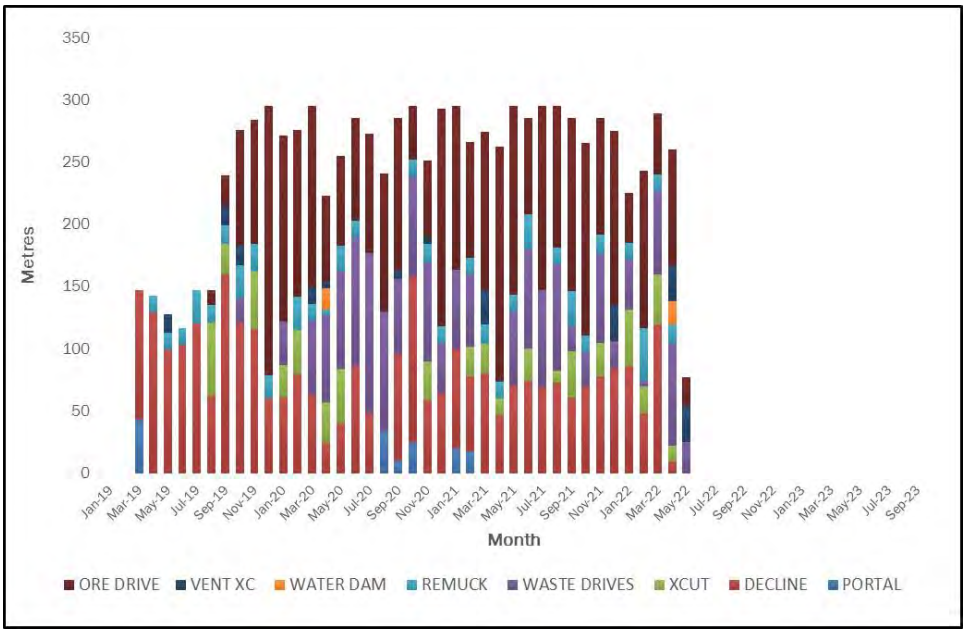
The statistics in Table 16.11 summarise the total development requirements.

**Table 16.11 Development Summary**

| Description | Unit | Summary of Development |
|---|---|---|
| Portal | m | 151 |
| Portal | $m^3$ | 2,228 |
| Decline | m | 2,931 |
| Decline | $m^3$ | 39,475 |
| Cross-cut | m | 583 |
| Cross-cut | $m^3$ | 5,246 |
| Waste Drives | m | 1,637 |
| Waste Drives | $m^3$ | 15,719 |
| Remuck | m | 523 |
| Remuck | $m^3$ | 10,598 |
| Water Dam | m | 36 |
| Water Dam | $m^3$ | 1,813 |
| Ventilation Cross-cut | m | 194 |
| Ventilation Cross-cut | $m^3$ | 1,760 |
| Ventilation Holes | m | 383 |
| Ventilation Holes | $m^3$ | 1,531 |
| Raisebore | m | 239 |
| Raisebore | $m^3$ | 1,692 |
| Slots | m | 3,119 |
| Slots | $m^3$ | 7,018 |
| Ore Drives | - | 3,599 |
| All Meters - Jumbo Rig | - | 9,654 |

The development schedule is depicted in Figure 16.25.

**Figure 16.25 Monthly Development Meters Scheduled**




## 16.2.8 Mine Production Schedule

The mine production schedule was developed using Datamine Studio 5D Planner and EPS software. Individual mining activities were developed and a practical mining sequence dictated the order of the mining activities. Applicable development and extraction rates were applied to each activity.

The key schedule drivers were:

- rate of individual development end advance
- total utilisation and efficiency of the jumbo development drill rig
- shifts and working hours available
- total advance that can be achieved because of development excavation availability.

The production schedules considered various production rates modelled within Studio 5D Planner and EPS software for each unique mining segment. All the necessary mining activities were developed within the Gantt-chart type scheduler, which is linked to the underground mine design. Mine depletion sequence rules governed the schedule progression, while the highest ore grade stopes were prioritised for extraction as early as possible. The first half of the silver profile graph (Figure 16.28) depicts the higher average value activities achieved with this particular mine production schedule.

Figure 16.26, Figure 16.27, and Figure 16.28 summarise the underground mine production schedule.

**Figure 16.26 Stope ROM Schedule**

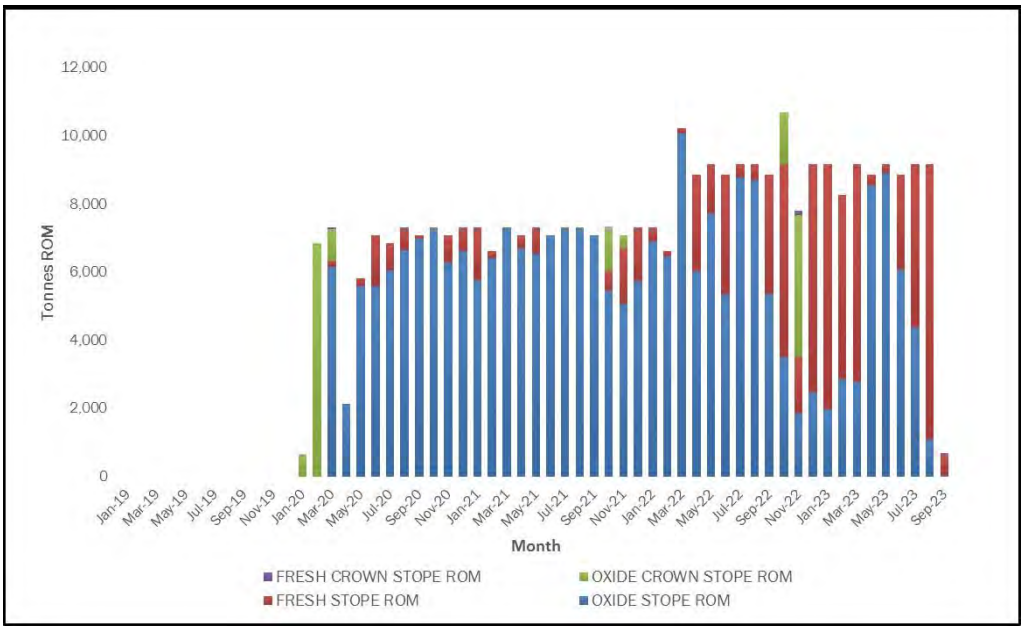



**Figure 16.27 Total ROM Production (Monthly)**

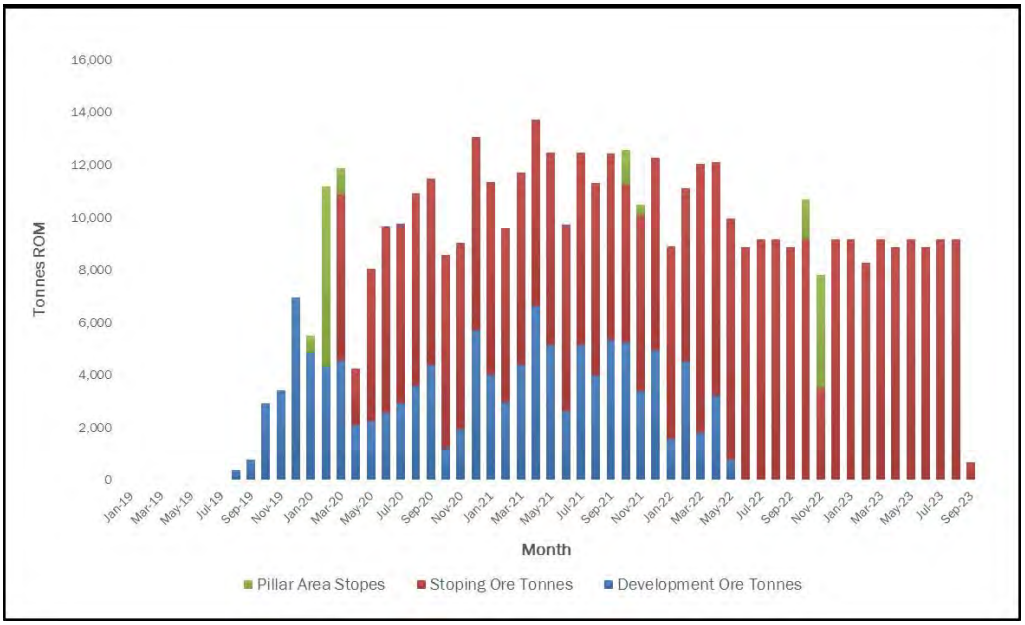


**Figure 16.28 Silver Profile (Monthly)**

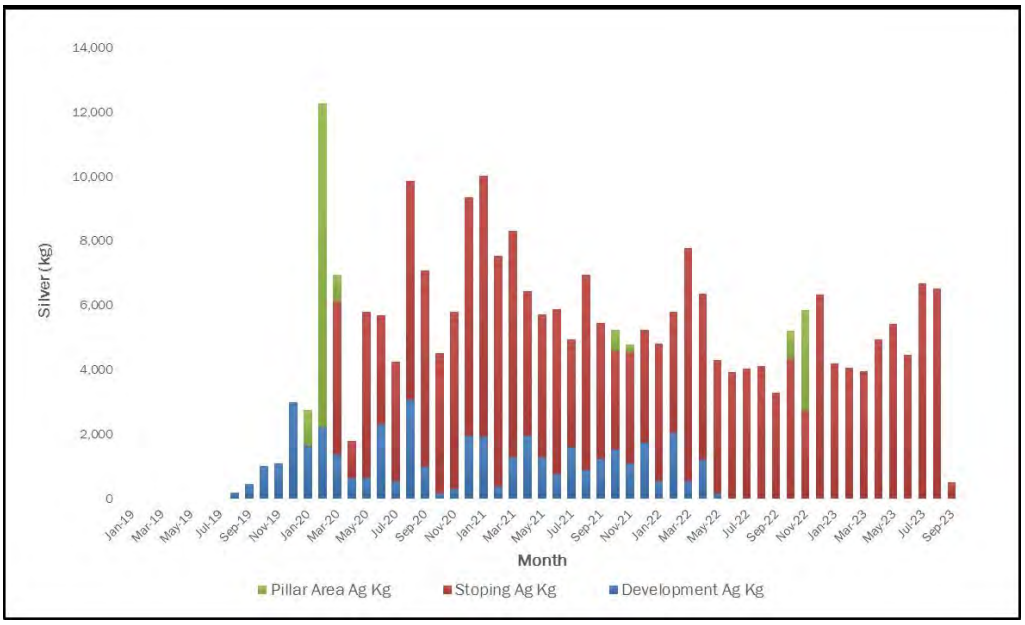
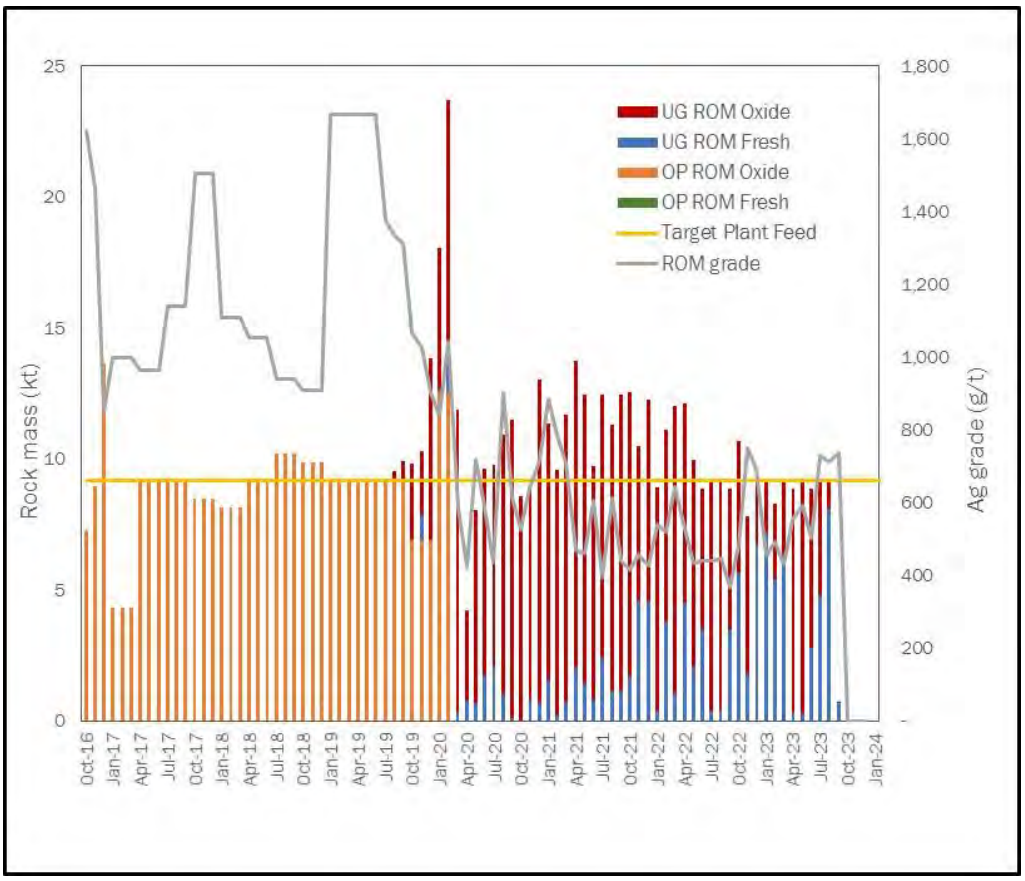



Figure 16.29 shows the combined mine production schedule. Note that the amount of fresh mineralisation increases to the end of the mine life.

**Figure 16.29 Combined Open Pit and Underground Schedule (Monthly)**



### 16.2.9 UNDERGROUND MINING EQUIPMENT

The mine design and excavation sizes are dependent upon the equipment selection. The starting point for any mine design is an understanding the production capacity requirements. From the production capacities, the typical loader and truck sizes are calculated. The number of active mining areas then dictate the amount of drilling that would be required to sustain the production capacity requirements, but also to enable the pre-development of areas for contingency measures.

The underground mining equipment for Vertikalny is shown in Table 16.12.

**Table 16.12 Equipment Units Simulated**

| Underground Units Operating | Maximum No. of Units |
|---|---|
| Jumbo – Single Boom Drill Rig | 1 |
| Charger – Small Explosive Charger Cars | 2 |
| Develop LHD – 3.7 t | 1 |
| Production LHD – 3.7 t | 1 |
| Develop Truck –17 t | 1 |
| Production Truck – 17 t | 1 |
| Shotcrete – Machine With Pump | 1 |
| Scissors Lift/Mechanical Lift | 1 |
| Long Hole Drill Rig | 1 |
| Small Motor Grader -Small Underground Grader | 1 |
| Carrier – People – Small Bus/Carrier | 1 |
| Fuel Carrier | 1 |
| Service Trucks – Utility/Small Trucks With Equipment Mounted | 2 |
| Pick-Up/Light Vehicles | 4 |

### 16.2.10 UNDERGROUND MINE OPERATIONS

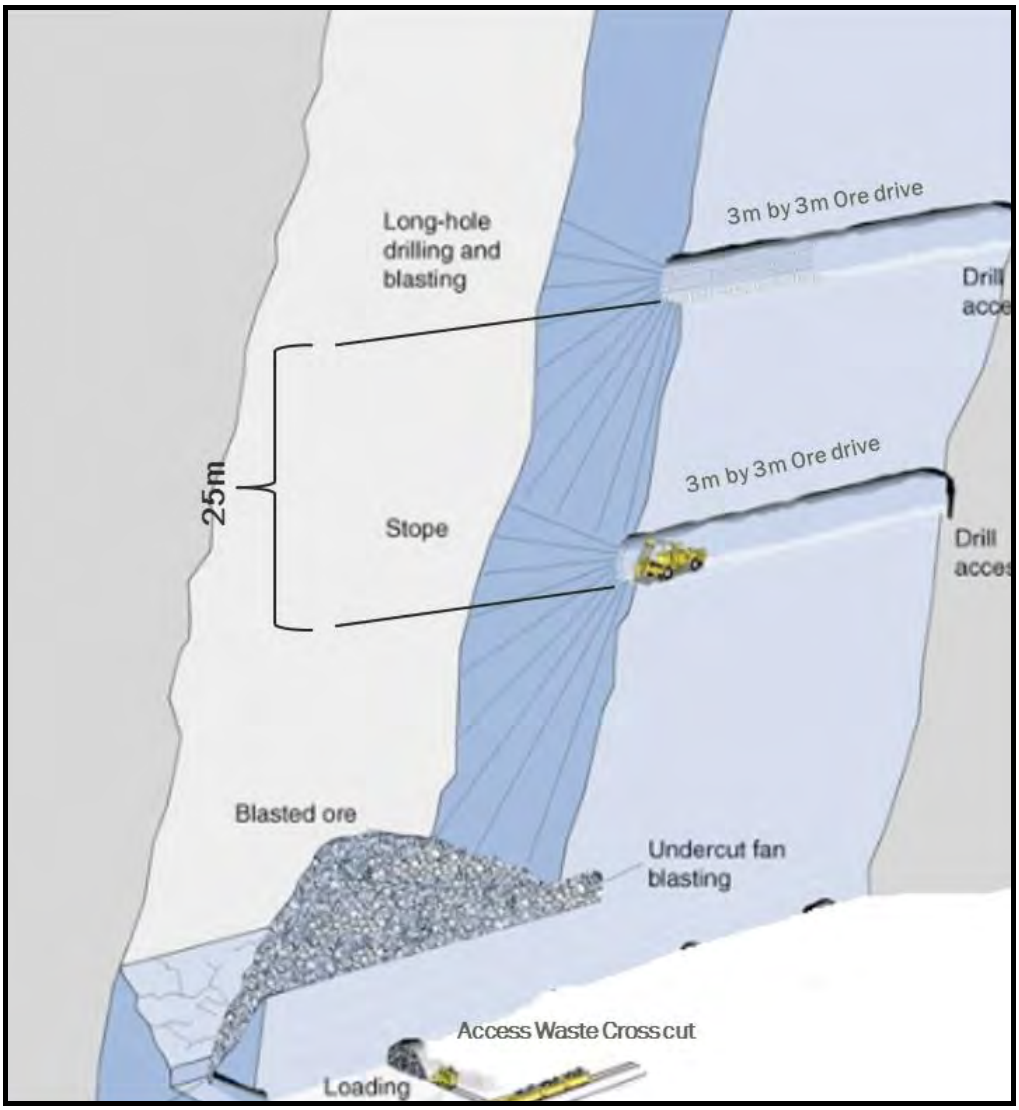
The underground exploitation strategy for Vertikalny is mechanised sub-level open stoping. The entry to the underground mine is gained through a main access decline in the North Zone and a series of in-pit adits in the South Zone. The adits and drives in South Zone is linked with a South Zone decline system.

The stoping method is best illustrated in Figure 16.30. The proposed mining extraction methods are:

- Ore drives minimum 3 m by 3.2 m
- Minimum stope blast width 1.3 m with a single line slightly staggered pattern (single line of 76 mm holes will break out approximately 1.25 m with additional slabbing around 1.3m in very good ground). Stope designed to less than 1.5 m stope widths accounts for 20% of all stope designs. The bottom sections of these stopes still have an ore drive of minimum 3.2 m width.

- 5% mining losses were applied to ore and a further 5% extraction loss to the typical stopes. A 10% extraction losses was applied to stopes near the crown pillar (in situ ore pillar left below the open pit final designs).
- Maximum stope width that can be mined (longitudinally) would be around 10 m before transverse open stoping becomes more practical and cost effective.
- The maximum designed stope width for Vertikalny is 3.9 m.
- The average stope width designed is 1.8 m.
- 17,000 t of Inferred material was included in the stope designs, but the metal from the Inferred material was not included in metal accounting. The Inferred ore tonnes are therefore calculated as part of stope dilution at 0 g/t silver grade.

**Figure 16.30 Mechanised Sub-level Open Stoping**



## 16.3 MINE CLOSURE

Spare operating hours for the dozers on site will be used to implement a progressive WRD rehabilitation. This can be achieved shortly after the end of the open phase as the underground mine produces very little waste rock.

The North and South Pits will not be backfilled. Each pit will be surrounded by a 1.5-m-high earth bund. During open pit mining the pits will be kept dry by pumping any water from the pit sumps to the surface collection ponds where it will be treated before discharge or used for processing.

It is expected that after the open pit phase is complete, water will report to the underground workings and discharge to the environment via the adits. The adits will be sealed with steel gates and the water allowed to drain via drain holes and raises to the lowest adit level of the mine. The main collection sump will situated on this level. During operations, water from the mine operations and any inflow from ground water would collect in the sump area. From here water will be topped up with fresh water (if required) and re-circulated to use in the mine as service water. SRK reports that, based on the current understanding of hydrogeology, the operating underground mine is expected to be a marginal consumer of water. Upon closure, the main collection sump would be enlarged to act as a long-term settler that would catch solids before any excess water from the workings enters the environment.

Should the underground mine be depleted and there are no economically feasible reason to continue with underground exploitation of the Vertikalny ore deposit, the following will have to be done during mine closure:

- remove all the ventilation fans (on retreat) from the underground operations
- shut and lock all underground ventilation doors and place no entry signs at each of these doors
- close of all other excavations and remove refuge chamber equipment
- place a permanent fence around the mine openings that prevents people from getting close to the openings and signpost the danger to entry
- clear all steel work and mine equipment and doze and rehabilitate the disturbed areas around the excavations (per the required environmental plan signed-off).

After the pillar recovery there may be some limited surface subsidence above the workings, but this will not be significant due to the narrow orebody geometry.

# 17.0 RECOVERY METHODS

## 17.1 SUMMARY

The process design for the Project is based on the test work presented in Section 13.0. The primary objective of the process design was to develop a flowsheet that is as simple to supply, operate, and maintain as possible, whilst maximising silver recovery and minimising power requirements.

The process flowsheet consists of a standard crushing and milling circuit, followed by gravity concentration and agitated tank leach of the gravity tails. The gravity concentrates will be processed by intensive cyanidation. The leached slurry from the tank leach and intensive cyanidation will go through a simple counter current decantation washing system and the solution will be processed by direct electrowinning to recover silver metal.

The process plant design will have provision for building additional leach tanks in order to process primary sulphide ore in the future.

Tailings from the process plant will comprise filtered solids and a blead stream from the depleted electrowinning solution and will be disposed of in the TMF.

## 17.2 PROCESS DESIGN CRITERIA

The process design criteria have been derived from the following sources of information:

- test work results, as reported in Section 13.0
- the mill production plan, as described in Section 16.0
- information published in the public domain, industry standard assumptions, and knowledge gained from similar projects and/or unit operations
- equipment manufacturers recommendations
- previous studies completed on the Project.

Table 17.1 lists a summary of the principle process design criteria established for the Project.

**Table 17.1 Process Design Criteria**

| Description | Unit | Value | Source |
|---|---|---|---|
| **General** | | | |
| Type of Deposit: | - | Silver Polymetallic | 5 |
| **Plant Operating Schedule** | | | |
| Shifts per Day | shifts | 2 | 1 |
| Hours per Shift | h | 12 | 1 |
| Hours per Day | h | 24 | 6 |
| Days per Year | d | 365 | 6 |
| Weeks per Year | wk | 52 | 6 |
| Operational Days per Year (Milling) | d | 336 | 1 |
| **Availability/Utilisation** | | | |
| Crushing Plant Utilisation | % | 75 | 7 |
| Crushing Plant Availability | % | 85 | 6 |
| Overall Annual Processing Rate | t/a (dry) | 110,000 | 9 |
| Daily Processing Rate | t/d | 402 | 2 |
| Operating Processing Rate | t/h | 39 | 2 |
| Milling Plant Utilisation | % | 92 | 7 |
| Milling Plant Availability | % | 91 | 6 |
| Overall Annual Processing Rate | t/a (dry) | 110,000 | 9 |
| Daily Processing Rate | t/d | 327 | 2 |
| Operating Processing Rate | t/h | 15 | 3 |
| Design Processing Rate | t/h | 20 | 2 |
| **Ore Characteristics – Design** | | | |
| Ore Specific Gravity | SG | 2.50 – 2.65 | 4 |
| Ore Bulk Density | $t/m^3$ | 1.60 | 6 |
| Ore Moisture Content | % | 5 | 6 |
| Bond Abrasion Index ($A_i$) (Average) | g/kWh | 0.039 | 4 |
| Bond Crushability Work Index ($CW_i$) | kWh/t | 7.7 | 4 |
| Bond Ball Mill Work Index ($BW_i$) | kWh/t | 14.6 | 4 |
| Head Grade (LOM) | g/t | 772 | 9 |
| **Metallurgical Recovery** | | | |
| Gravity Silver Recovery (Lab) | % | 7.9 | 4 |
| Gravity Silver Recovery (Plant Conditions) | % | 7.9 | 2 |
| Intensive Leach Dissolution (Gravity Concentrate) | % | 98.0 | 4 |
| Leach Dissolution (Gravity Tails) | % | 85.8 | 4 |
| Overall Silver Dissolution | % | 86.7 | 2 |
| Electrowinning Efficiency | % | 99.0 | 4 |
| Silver Recovery (Oxides) | % | 85.0 | 2 |
| Silver Recovery (Primary) | % | 69.6 | 2 |
| **Crushing** | | | |
| Average Tonnage Rate (Operating Total ROM Deed) | t/h | 39 | 3 |
| Average Crusher Tonnage Rate (Design) | t/h | 45 | 2,3 |

*table continues...*

| Description | Unit | Value | Source |
|---|---|---|---|
| Average Crusher Volumetric Rate (Design) | $m^3/h$ | 17 | 2 |
| ROM Feed $F_{80}$ | mm | 200 | 6 |
| Operating Shifts per Day | shift/d | 1 | 1 |
| Operating Hours per Shift | h/shift | 12 | 1 |
| Operating Days per Week | d | 6 | 6 |
| Primary Crusher Type | - | Jaw (Metso C80 - Equivalent) | 2,3,7 |
| Number of Crushers | - | 1 | 2,3,7 |
| Crusher Feed Particle Size $F_{95}$ | mm | 300 | 6 |
| Crusher Feed Particle Size $F_{80}$ | mm | 200 | 6 |
| Crusher Product Particle Size $P_{80}$ | mm | 50 | 6 |
| Reduction Ratio | - | 4.00 | 2 |
| Closed Side Setting | mm | 40 | 6 |
| **Secondary Crushing** | | | |
| Secondary Screen | type | Horizontal Vibrating | 6 |
| Area | $m^2$ | 1.4 | 2 |
| Number Needed | - | 1 | 2 |
| Motor Size | kW | 5 | 8 |
| Deck Aperture Size | mm | 20 | 6 |
| Secondary Crusher | type | Fine Cone (Metso GP 100 - Equivalent) | 6 |
| Motor Size | kW | 90 | 8 |
| Product Size ($P_{80}$) | mm | 13 | 6 |
| Closed Side Setting | mm | 13 | 8 |
| Stroke | mm | 16 | 8 |
| **Fine Ore Bin** | | | |
| Number of Discharge Conveyors | - | 1 | 2,3,7 |
| Product Size on Discharge Conveyor (Design) $P_{80}$ | mm | 13 | 2 |
| Number of Feeders | - | 1 | 2,3 |
| Type of Feeders | - | Vibrating | 2,3,7 |
| Average Tonnage Rate per Stream (Operating) | t/h | 15 | 3 |
| Design Tonnage Rate | t/h | 20 | 2,3,7 |
| **Grinding** | | | |
| Primary Mill Type | - | Wet Overflow Ball Mill | 5 |
| Mill Size (diameter x length) | m x m | 2.8 x 4.9 | 2,8 |
| Motor Size | kW | 475 | 2,8 |
| Number of Mills | - | 1 | 2 |
| Bond $W_i$ – Ball Mill (Design) | kWh/t | 14.6 | 2,4 |
| Average Fresh Feed Tonnage Rate | t/h | 15 | 3 |
| Solids/Pulp Density | % | 65 | 6 |
| Top Feed Size | µm | 18,000 | 6,7 |
| Feed Size ($F_{80}$) | µm | 13,000 | 2,6,7 |
| Product Size ($P_{80}$) – Oxide ore | µm | 75 | 2,4 |
| Product Size ($P_{80}$) - Primary ore | µm | 25 | 2,4 |

*table continues..*

| Description | Unit | Value | Source |
|---|---|---|---|
| Ball Mill Recycle Load | % | 250 | 3,6 |
| Mill Speed | % CS | 70-75 | 7 |
| Mill Ball Charge | % VB | 30-35 | 8 |
| **Classification Cyclone** | | | |
| Number of Cyclone (operating) | - | 1 | 2,8 |
| Number of Cyclone (standby) | - | 1 | 6,8 |
| Number of Cyclones (total) | - | 2 | 2,6,8 |
| Cyclone Size Diameter | mm | 508 | 2,8 |
| Inlet Diameter | mm | 150 | 8 |
| Vortex Finder | mm | 150 | 8 |
| Apex | mm | 76 | 8 |
| Product Size $P_{80}$ | µm | 75 | 2,8 |
| **Dewatering Cyclones** | | | |
| Number of Cyclone (Operating) | - | 1 | 2,8 |
| Number of Cyclone (Standby) | - | 1 | 6,8 |
| Number of Cyclones (Total) | - | 2 | 2,6,8 |
| Cyclone Size Diameter | mm | 508 | 2,8 |
| Inlet Diameter | mm | 150 | 8 |
| Vortex Finder | mm | 100 | 8 |
| Apex | mm | 38 | 8 |
| Overflow Pulp Density (nominal) | % solids | 0 | 6 |
| Underflow Pulp Density | % solids | 70 | 6 |
| **Gravity Concentration** | | | |
| Configuration | - | Leach Feed | 7 |
| Material Split | % | 100 | 6 |
| Throughput | t/h | 15 | 2,3 |
| Safety Screen | type | Knelson | 6 |
| | size | 7m X 16m | 8 |
| Screen Aperture | mm | 1mm | 8 |
| Number of Screens | - | 1 | 2,8 |
| Gravity Concentrator | type | Knelson XD 20MS | 8 |
| Number of Concentrators | - | 1 | 2,8 |
| Maximum throughput | t/h | 80 | 8 |
| Design Throughput | t/h | 15 | 2,3 |
| Cone Style | - | G6 | 8 |
| G- Force range | G | 60-120 | 8 |
| Operating Mode | - | Semi Continuous | 7 |
| Concentrate Flush Sequence | flush/h/unit | 2.4 | 8 |
| Fluidisation Water Requirement | $m^3$/h/unit | 15 | 8 |
| Concentrate Mass Pull | % | 0.1 | 2,8 |
| Concentrate Production | kg/h/unit | 32 | 2,3 |
| Concentrate Production | kg/d | 777 | 2,3 |
| Gravity Silver Recovery | % | 7.9 | 2 |
| Concentrate Grade | g/t | 32,917 | 2 |
| **Concentrate Regrind Mill** | | | |
| Type | - | Vertimill/Tower Mill | 6 |

*table continues..*

| Description | Unit | Value | Source |
|---|---|---|---|
| Design Capacity | t/d | 1 | 2 |
| Installed Power | kW | 15 | 8 |
| Mode of Operation | - | Batch | 6 |
| Sequence of Operation | batch/d | 1 | 6 |
| Intensive Leach Reactor | - | ACACIA CS 1000 | 8 |
| Number of Reactors | - | 1 | 2,8 |
| Mode of Operation | - | Batch | 7 |
| Sequence of Operation | batch/d | 1 | 2 |
| Design Capacity | t/d | 1 | 8 |
| Cycle Time | - | | |
| Pre-wash | min | 30 | 8 |
| Intensive Leach | h | 16 | 8 |
| Reagents | kg/t | NaOH-1.5, NaCN-15.0 | 8 |
| Silver Dissolution | % | 98.0 | 2,4 |
| **Leach Circuit** | | | |
| Solids Feed Rate | t/h | 15 | 3 |
| Number of Parallel Trains | no. | 1 | 6 |
| Feed Rate per Train | t/h | 15 | 2 |
| Pulp Density | % solids | 45 | 2,3 |
| Nominal Flow Rate | $m^3/h$ | 24 | 2,3 |
| Processing Method | - | Agitated Tank leach | 5 |
| **Leach Tanks** | | | |
| Type | - | Mechanical Agitation | 6 |
| Number of Tanks per Train | - | 6 | 2 |
| Operating Volume (each) | $m^3$ | 313 | 2 |
| Nominal Resident Time (total) | h | 72 | 4 |
| Nominal Resident Time (each) | h | 12 | 2 |
| Tank Dimensions | m x m | 7.35 X 7.35 | 2 |
| Impeller Type | - | TBC | 8 |
| Bottom Clearance (approximate) | m | TBC | 8 |
| Impeller Clearance (approximate) | m | TBC | 8 |
| Motor Power | kW | TBC | 2,8 |
| Leach Air Requirement | l/min | 371 | 2,7 |
| **Washing Circuit** | | | |
| *Dewatering Cyclones* | | | |
| Feed Rate | t/h | 15 | 3 |
| Number of Cyclone (operating) | - | 1 | 2,8 |
| Number of Cyclone (standby) | - | 1 | 2,6,8 |
| Number of Cyclones (total) | - | 2 | 2,8 |
| Cyclone Size Diameter | mm | 508 | 2,8 |
| Inlet Diameter | mm | 150 | 2,8 |
| Vortex Finder | mm | 100 | 2,8 |
| Apex | mm | 38 | 2,8 |
| Overflow Pulp Density (nominal) | % Solids | 5 | 2,8 |
| Underflow Pulp density | % Solids | 60 | 2,8 |

*table continues...*

| Description | Unit | Value | Source |
|---|---|---|---|
| **Clarifiers** | | | |
| Clarifier Type | - | 9 m high-rate Clarifier | 2 |
| Number of Thickeners | - | 1 | 2,8 |
| Clarifier Diameter | m | 9.00 | 2,8 |
| Clarifier Underflow Solid Density | % | 40-50 | 2,8 |
| Overflow Pulp Density (nominal) | ppm | 100 | 8 |
| Slurry Transportation Method | - | Pumping | 2,8 |
| Flocculent Consumption | g/t | 25 | 2,4 |
| Flocculent Solution Strength | g/L | 0.5 | 6 |
| Flocculent Plant Capacity | kg/h | 50 | 6 |
| Flocculent Holding Tank Capacity | h | 2.00 | 6 |
| **Filters** | | | |
| Filter Type | - | Plate & Frame (Recessed Type) | 8 |
| Size | m x m | 2 X 2 | 8 |
| Number of Chambers | - | 60.00 | 8 |
| Filter Cake Moisture Content | % | 15.00 | 6 |
| **Electrowinning** | | | |
| Primary Electrowinning | type | EMEW Powder cell | 8 |
| Number of Cells | - | 140 | 2,8 |
| Cell Diameter | mm | 200 | 8 |
| Operating Schedule | h/d | 24 | 6 |
| Type of Cathode | - | 316SS | 7,8 |
| Type of Anode | - | 316SS | 7,8 |
| Cathode Sludge Removal Method | - | Pressure Back Wash | 7,8 |
| Secondary Electrowinning | type | EMEW Polishing Cell | 8 |
| Number of Cells | - | 80 | 2,8 |
| Cell Diameter | mm | 200 | 8 |
| Operating Schedule | h/d | 24 | 6 |
| Type of Cathode | - | 316SS | 7,8 |
| Type of Anode | - | 316SS | 7,8 |
| **Precipitate Filtration** | | | |
| Filter Type | - | Plate and Frame, Pneumatic/Hydraulic Closure | 7,8 |
| Capacity | L | 85 | 2,8 |
| Operating Hours per Day | d | 6 | 6 |
| Filter Cake Moisture | % | 20 | 6 |
| **Drying** | | | |
| Type | | Electric Oven | - |
| Drying Temperature | C | 105-120 | - |
| Operating schedule | | Daily | - |
| Final Product Moisture Content | % | 2- 4 | - |

## 17.3 AVAILABILITY AND UTILISATION

The crushing plant was designed based on 274 operational days per year, to allow 2 days per month of planned shut down for scheduled maintenance and housekeeping, and approximately 2 months of shut down for extreme winter. The crushing plant is expected to have an availability of 75%, with 85% utilisation, in order to give an effective utilisation of 64%.

The milling and leaching plants were designed based on 335 operational days per year, to allow 2.5 days per month of planned shutdown, and to provide 92% availability. The plant utilisation is expected to be 91%, in order to give an 84% effective utilisation.

The ore stockpile was designed with sufficient surge capacity to provide an uninterrupted supply to the mill in order to maintain a high utilisation during the crusher shut down periods.

## 17.4 LOCATION AND LAYOUT

The proposed process plant will be located on the top of the hill approximately 1,250 masl and northeast of the open pit mining area. The ROM pad, crushers, and conveyers will be located southwest of the process plant to facilitate material handling and crushing from the mining area.

The TMF will be located southeast of the process plant and will handle the dewatered tails from the process plant.

The electrowinning section, office buildings, and metallurgical laboratory will be located within the process plant premises and near the plant access road.

The plant access road will connect the process plant on the top of the hill to the camp facilities located in the valley bottom.

## 17.5 PRIMARY EQUIPMENT LIST

The primary equipment list (Table 17.2) was prepared based on the process design criteria presented in Table 17.1.

**Table 17.2 Primary Equipment List**

| Plant Major Equipment | No. of Units | Installed Power/Unit (kW) | Total Installed Power (kW) |
|---|---|---|---|
| Vibrating Grizzly | 1 | 12 | 12 |
| Vibrating Feeder | 1 | 12 | 12 |
| Primary Crusher | 1 | 148 | 148 |
| Crusher Screen Feed Conveyor | 1 | TBD | 0 |
| Secondary Crusher Screen | 1 | 12 | 12 |
| Secondary Crusher Feed Conveyor | 1 | TBD | 0 |
| Secondary Crusher | 1 | 120 | 120 |
| Secondary Crusher Discharge Conveyor | 1 | TBD | 0 |
| Fine Ore Bin Feed Conveyor | 1 | 18 | 18 |
| Electric Overhead Travelling Crane | 1 | 18 | 18 |
| Fine Ore Bin | 1 | 0 | 0 |
| Fine Ore Bin Vibrating Feeder | 1 | 12 | 12 |
| Ball Mill Feed Conveyor | 1 | 12 | 12 |
| Ball Mill Feed Chute | 1 | 0 | 0 |
| Ball Mill ) | 1 | 475 | 475 |
| Ball Mill Scats Bin | 3 | 0 | 0 |
| Ball Mill Ball Hopper | 1 | 0 | 0 |
| Ball Mill Liner Handler | 1 | 1 | 1 |
| Mill Area Sump Pump | 2 | 15 | 30 |
| Mill Area Sump Pump | 0 | 15 | 0 |
| Mill Discharge Pump Box | 1 | 0 | 0 |
| Mill Classifying Cyclone Feed Pump | 2 | 20 | 40 |
| Mill Classifying Cyclone Feed Pump | 0 | 20 | 0 |
| Mill Classifying Cyclone | 1 | 0 | 0 |
| Mill Classifying Cyclone Overflow Tank | 1 | 0 | 0 |
| Mill Classifying Cyclone Overflow Tank Agitator | 1 | 12 | 12 |
| Mill Dewatering Cyclone Feed Pump | 2 | 18 | 35 |
| Mill Dewatering Cyclone | 1 | 0 | 0 |
| Intensive Leach Package | 1 | 30 | 30 |
| Gravity Trash Screen | 1 | 12 | 12 |
| Gravity Concentrator | 1 | 6 | 6 |
| Gravity Concentrate Tank | 1 | 0 | 0 |
| Regrind Mill | 1 | 8 | 8 |
| Regrind Mill feed pump | 1 | 4 | 4 |
| Gravity Tailings Pump Box | 1 | 0 | 0 |
| Gravity Tailings Pump | 2 | 12 | 24 |
| Leach Tank 1 | 6 | 0 | 0 |
| Leach Tank Agitator 1 | 6 | 60 | 360 |
| Leach Blowers | 1 | 15 | 15 |
| Leach Air Receiver | 1 | 0 | 0 |
| Leach Discharge Pump Box | 1 | 0 | 0 |
| Leach Discharge Pump | 2 | 15 | 30 |
| Leach Area Sump Pump | 4 | 15 | 59 |

*table continues...*

| Plant Major Equipment | No. of Units | Installed Power/Unit (kW) | Total Installed Power (kW) |
|---|---|---|---|
| Lamella Thickener Feed Tank | 1 | 0 | 0 |
| Lamella Thickener Feed pump | 1 | 12 | 12 |
| Lamella Thickener | 1 | 0 | 0 |
| Clarifier Under Flow Pump | 2 | 12 | 24 |
| Leach Dewatering Cyclone | 1 | 0 | 0 |
| Filter Press Charge Tank | 1 | 0 | 0 |
| Filter Press Charge Tank Agitator | 1 | 12 | 12 |
| Filter Press Charge Pump | 2 | 12 | 24 |
| Clarifier Over Flow Pump Box | 1 | 0 | 0 |
| Clarifier Over Flow Pump | 2 | 12 | 24 |
| Filter Press | 2 | 12 | 24 |
| Filter Cake Discharge Conveyor | 1 | 12 | 12 |
| Electrowinning Package Polishing Cells | 1 | 63 | 63 |
| Electrowinning Package Powder Cells | 1 | 263 | 263 |
| Sludge Drying Package | 1 | 12 | 12 |
| Sump Pump | - | 15 | 0 |
| Lime Package | 1 | 12 | 12 |
| Caustic Package | 1 | 12 | 12 |
| Flocculant Package | 1 | 4 | 4 |
| Cyanide Package | 1 | 12 | 12 |
| Sump Pump | 1 | 15 | 15 |
| Process Water Tank | 1 | 0 | 0 |
| **Total Installed Power (kW)** | - | - | **2,028** |

## 17.6 PROCESS DESCRIPTION

### 17.6.1 PROCESS DESCRIPTION OVERVIEW

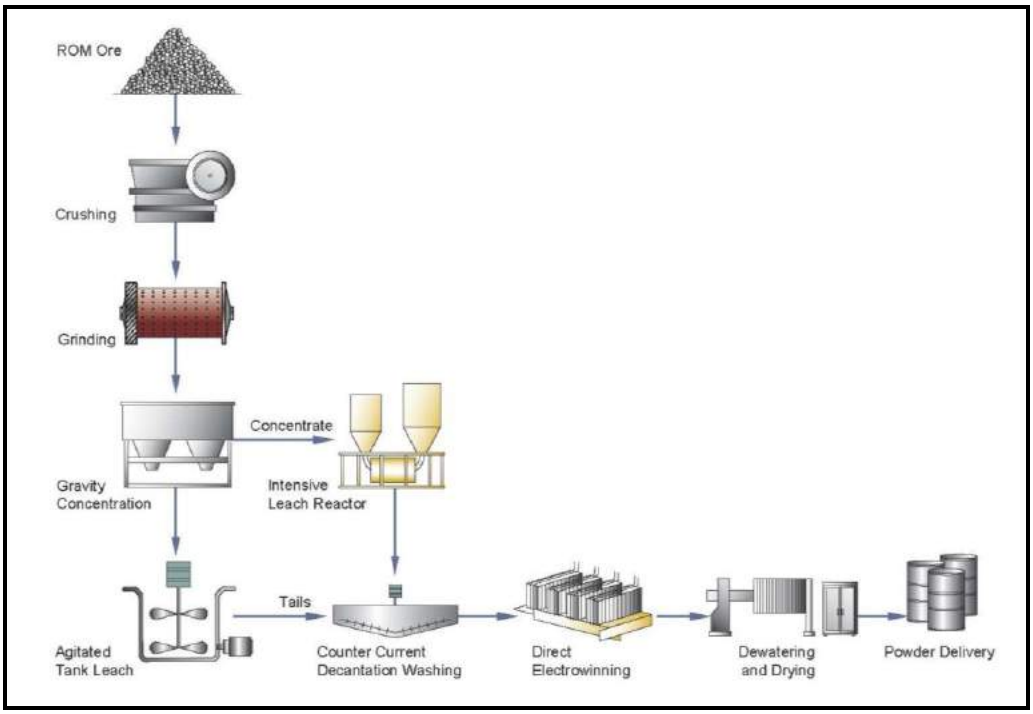
A standard crushing and milling circuit will be employed to produce a suitable feed for gravity concentration and cyanide leaching at a size of typically 80% minus 75 µm. The gravity concentrate will be leached in an Intensive Leach Reactor (ILR), such as an ACACIA reactor in order to dissolve the high-grade silver from the gravity concentrate with cyanide. The resultant silver-bearing solution from the ILR will then be pumped directly to the dewatering circuit prior to the direct electrowinning process.

The gravity tailings will be cyanide leached to dissolve the silver into a high-grade leach solution. Conventionally, with such high-grade silver ore, a Merrill Crowe process would then be used to recover silver from the solution. The unit processes involved would typically include counter-current decantation (CCD) or filtration for recovery of the silver-bearing solution from the solids, followed by de-aeration, clarification and recovery of the silver using zinc powder, followed by acid digestion, filtration, and smelting. The Merrill Crowe process is both costly and complex to operate and maintain and is not considered ideal for the Project.

Due to exceptionally high silver grades, and the requirement to avoid the Merrill Crowe process, the proprietary direct electrowinning process was selected as the appropriate technology. In this technique, the high-grade, silver-rich solution from the leaching process is passed directly to specially constructed electrowinning cells for direct recovery of the silver onto cathodes that can be washed periodically, dewatered dried and drummed for shipment. This considerably reduces the capital cost, is easier to operate and maintain, and should lend itself to a compact modular design.

The dry solids tailings produced from the selected flowsheet will be dry stacked into the TMF. A block flow diagram of the process plant is shown in Figure 17.1.

**Figure 17.1 Block Flow Diagram of the Proposed Process Plant**




Source: Tetra Tech

## 17.6.2 CRUSHING

ROM mineral with a maximum size of approximately 300 mm and 80% passing 200 mm will be trucked to the ROM pad, and the material will feed into the crushing and screening circuit. The crushing and screening unit will be arranged for closed circuit crushing. The crushing circuit will operate over a single 12-hour shift to allow for maximum efficient running of the circuit crushers, which have been sized as per the standard crusher supply.

The ROM mineral will feed to a vibrating grizzly where the fine ore will be removed and passed directly to the secondary crushing circuit screen. The coarse fraction will be crushed in the primary jaw crusher, such as a Metso C80 or equivalent. The product from the jaw crusher will be sent to the secondary crushing circuit screen.

The secondary crushing circuit will contain a secondary cone crusher, such as Metso GP100 or equivalent, operating in closed circuit with a single deck screen to produce

a final screen product with a $P_{80}$ of 13 mm, suitable for the ball mill feed. The screen undersize from the secondary crushing circuit will be conveyed to a crushed ore bin where it will be reclaimed and fed to the processing plant as required.

The crushing circuit is designed to operate at 75% availability to allow for operational and mechanical maintenance and winter shut down. Spare sets of jaw and cone crusher liners will be kept on site.

A process flow diagram of the crushing circuit can be seen in the Appendix D.

### 17.6.3 Milling and Gravity

#### *Milling*

The milling and processing plant will operate for 24 h/d at an availability of 91% and process 327 t/d of mineral at an average silver head grade of 772 g/t.

The crushed material will feed directly onto the ball mill via a feed conveyor belt and feed hopper. The conveyor belt will be equipped with a weightometer and a sampler from which the primary accounting information will be obtained (i.e. the throughput, silver head grade, and moisture content).

A single ball mill will be used to achieve the required grind size for effective gravity concentration/flotation and cyanide leaching. The ball mill will be a standard open discharge mill operating in closed circuit with two stages of hydrocyclones in order to produce a ground product suitable for the downstream gravity concentration and leaching process.

The estimated size of the ball mill is 2.8 by 4.9 m installed with a 475 kW motor. Steel ball grinding media will be added to the ball mill feed using a wheeled crane and kibble, with the balls added to the mill feed hopper. Water will be added to the mill feed inlet to achieve an operating mill pulp density of approximately 60 to 65% solids by weight.

The mill product slurry will be pumped to a two-stage cyclone system, where the primary cyclone will function as a classifier with a separation of size of $P_{80}$ = 75 µm for oxide ore and $P_{80}$ = 25 µm for primary ore. The underflow from the primary cyclone will be recirculated back to the ball mill with a design recirculating load of 250%. The overflow from the primary cyclone will be densified at the second cyclone to approximately 45 to 50% solids, and gravitate to the gravity concentration circuit during the normal operation. The overflow from the densifying cyclone will be pumped to the process water tank. It is anticipated that the solids content of this overflow will nominally be zero.

It is important to note additional milling capacity may be required in the future when the primary ore is processed through the plant,

The process flow diagram of the milling circuit can be seen in Appendix D.

#### GRAVITY CIRCUIT

The gravity concentration circuit will consist of a trash screen followed by a Knelson gravity concentrator. The trash screen will remove any tramp material, plastic, wood, etc. and the undersize will gravitate to the gravity concentrator which effectively recovers the complex silver minerals into the gravity concentrate. A Knelson concentrator uses centrifugal forces generated in a spinning bowl to enhance gravity separation of silver minerals. The slurry will be fed into a spinning bowl which throws the solids towards the bowl perimeter forming a solid bed. Fluidisation water will be injected into the bowl to maintain the bed fluidisation and to facilitate the movement of the light particles out of the bed; these will be discharged via the overflow. The solid particles will migrate down into the rings within the spinning bowl where the heavy minerals are concentrated. The heavy particles will be recovered by periodically flushing the bowl with water. The gravity tailings will be pumped to the first of the agitated leach tanks.

The high-grade gravity concentrate flushed from the Knelson concentrator will collect in a tank for subsequent regrinding and intensive cyanidation. The concentrate regrinding will be achieved in a tower mill, or equivalent, with installed motor power of 15 kW.

The regrind mill will operate as a batch process where approximately 0.8 tons of concentrate will be milled every day to $P_{80}$ = 25 µm in size.

The reground concentrate will be transferred on to a Consep ACACIA intensive leach reactor for cyanidation. The ACACIA system is made up of a reagent conditioning tank and a flow fluidised reactor for the leaching process. Slurry will feed into the reactor where reagents will be pumped from the conditioning tank, up through the reactor, fluidising the solids within the slurry, ensuring maximum contact between solids and reagents.

The resulting high-grade silver solution from the ACACIA reactor will be pumped to a clarifier prior to the direct electrowinning process. The leached solids from the ACACIA reactor will be pumped back to the mill.

It is important to note that the entire gravity circuit will be bypassed during the times when primary ore is processed through the plant.

The process flow diagram of the gravity circuit can be seen in Appendix D.

### 17.6.4 LEACHING

Leaching of the gravity tails will be completed in agitated leach tanks, designed to give a total residence time of approximately 72 hours. However, provision will be made to construct additional tanks to increase the residence time to 120 hours in the future, when the primary ore is processed.

The leach tanks will be constructed on progressively lower elevations to allow the flow of slurry from tank to tank using gravity. The leach tanks will be constructed of mild steel, with an active volume per tank of approximately 312 $m^3$ with an agitator installed. Each leach tank will be equipped with a gas sparger for injection of air into

the slurry in order to maintain the required oxygen level in the solution for acceptable process kinetics.

The leach tanks will be constructed with manually operated valves in order to direct the flow through a by-pass line traversing the tank when required.

At the end of the leaching, slurry from the last leach tank will be pumped to the dewatering circuit in order to separate the solids and solution for direct electrowinning.

Lime slurry and cyanide solution will be added to the leach tanks to maintain a pH of approximately 11.5 and free cyanide concentration at least 2, 000 ppm throughout the leaching. The lime slurry and cyanide solution will be prepared in the reagent preparation area and pumped into a ring main, where additions can be made to the leach tanks as required.

The process flow diagram of the leach circuit can be seen in Appendix D.

### 17.6.5 Dewatering, Filtration and Clarification

Solid-liquid separation of the leach product will be achieved using a combination of a dewatering hydrocyclone, a plate and frame filter press, and a high-rate clarifier. The slurry from the last leach tank will be pumped through a dewatering hydrocyclone. The hydrocyclone overflow will be further clarified in a high-rate clarifier in order to provide a suitable overflow solution for the direct electrowinning process.

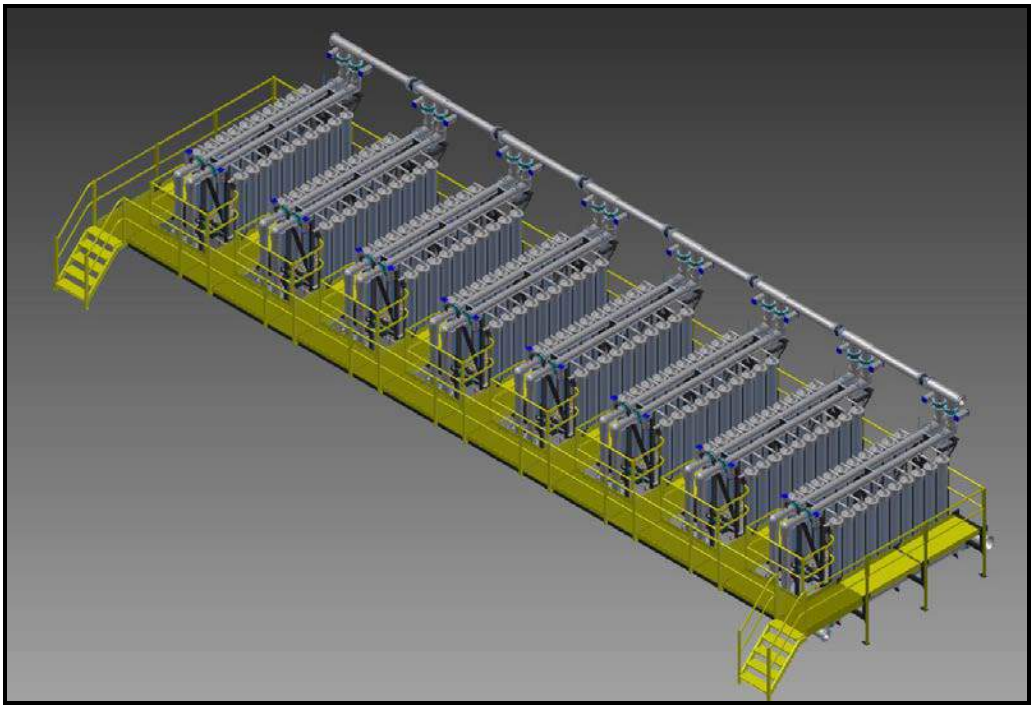
The hydrocyclone underflow will pass into an agitated filter feed tank. From there, the slurry will be pumped to a plate and frame filter press. A buffer tank was installed prior to the filter press to allow for the batch operation of the unit. The filter press cycle will include a wash cycle to remove any silver containing solution from within the leached solid tailings. The wash water will also remove any cyanide that is associated with the filtered solids. The filter press filtrate will feed into the clarifier, with the filtrate produced during the filter cake wash returning to the water recycle circuit for re-use within the plant. The solid product from the filter press will be conveyed to the TMF.

The process flow diagram of the dewatering circuit can be seen in Appendix D.

### 17.6.6 Direct Electrowinning

The direct electrowinning process will employ patented emew® cell technology (Figure 17.2) to recover silver, which can be directly smelted to produce doré silver bars or alternatively the precipitate can be shipped directly to the refinery. The direct electrowinning circuit will be operated in two stages, with both stages consisting of emew® cells.

**Figure 17.2 3D Model of an emew® Cell Technology**



The primary stage, consisting of 140 emew® powder cells, each 200 mm in diameter will reduce the silver solution from approximately 800 ppm to 50 ppm silver. The secondary stage, consisting of 80 emew® polishing cells, each 200 mm in diameter will reduce the solution to below 10 ppm silver prior to discharge. The entire direct electrowinning plant will be supplied as a modular turnkey package plant by Electrometals.

The individual emew® cells will be constructed from a pair of tubular electrodes and the ends fitted with plastic end caps, allowing high flow and efficient mixing through the closed chamber formed. The capacity of each cell will depend on the silver concentration feeding to the electrowinning circuit; the more diluted the feed, the larger the electrowinning circuit required.

The inside surface of the pipe is the cathode and will be constructed of stainless steel. The anode, which will also be of stainless steel construction, runs through the centre of each cell. During operation, high-grade silver will be deposited on the cathode surface (Figure 17.3) and automatically flushed from the cell by a back wash technique and collected in a tank for filtration and drying before being packed into drums for shipping into a suitable refinery.

**Figure 17.3 Silver Powder Deposition on Cathode Surface**

Barren solution from the electrowinning process will return to the process water tank and subsequently used as dilution water for mill feed, or used for slurry density control purposes in the leach circuit. It is anticipated that approximately 1% of the barren solution will be discharged following cyanide detoxification in order to avoid a build-up of base metal and deleterious elements within the recycle stream.

The process flow diagram of the direct electrowinning circuit can be seen in Appendix D.

## 17.7 PLANT SERVICES AND REAGENTS

Typical plant services include an air compressor to supply air to the agitated leach tanks for effective silver dissolution and for instrument air. It is expected that plant instrumentation will be minimal.

### 17.7.1 WATER

Fresh water will be supplied to a dedicated process water tank and process water pumps will deliver water as required to the plant. Barren solution will be recycled as part of the process to prevent excess fresh water requirements; however, this will be limited to ensure that there is no build-up of deleterious elements within the slurry streams. Approximately 1% of the barren electrowinning solution will be sent to a detoxification circuit for cyanide detoxification and disposal.

### 17.7.2 CYANIDE AND LIME

The principal reagents are cyanide and lime. Lime will be delivered to site in 1-t bulk bags as hydrated lime powder. The lime will be mixed in a dedicated agitated mixing tank, typically with a capacity for one day's consumption, and transferred to a storage tank where water will be added and the resulting lime slurry pumped into a ring main system delivering the lime to the leaching circuit to maintain the pH at 11.5 as required. The lime bags will be added to the mixing tank using a hoist and bag-

breaker installed above the tank. Lime bags will be stored in a dedicated covered storage area.

Cyanide will be delivered to site as 1-t bulk bags containing sodium cyanide briquettes. The briquettes will be added to an agitated cyanide mixing tank, with the required volume of water, by hoisting the bag onto a bag-breaker situated above the tank and enclosed in a steel chute for dust control. The cyanide solution will be made up to approximately 25% concentration.

A split tank system can be used, whereby two-thirds of the tank would be dedicated to cyanide mixing, and the remaining third used as storage, from which the cyanide solution is pumped via the ring main to the leaching circuit as required to maintain an initial cyanide concentration of approximately 500 ppm in the first leach tank. A bunded concrete spillage area with a dedicated sump pump is required.

Cyanide bags are normally stored in containers with access for a forklift.

A dedicated wheeled crane is required for general plant use, steel ball addition, maintenance, and reagent preparation together with a dedicated fork lift.

### 17.7.3 Power and Mobile Equipment

Electricity for the process plant will be supplied from the on-site power plant.

One dedicated wheeled crane will be required for general plant use, maintenance, and reagent preparation, together with the additional mobile plant equipment listed in the primary equipment list (Table 17.2).

### 17.7.4 Laboratory

A fully equipped laboratory will be available on site and will have the following separate areas:

- a sample preparation sector with a space/bench area for sample receiving, drying ovens, size reduction equipment, and adequate bench space for the preparation of mine and geological samples
- an assay laboratory with separate sample preparation and storage areas for samples sourced from different zones of the orebody in order to avoid cross contamination; the laboratory will contain fire assay equipment, scale room, chemical laboratory analysis, and chemical storage
- a metallurgical laboratory including pressure filters, grinding simulation equipment, leaching test equipment, and other miscellaneous metallurgical laboratory equipment as required.

## 17.8 Control Philosophy

The control philosophy for the process plant was developed to achieve the following objectives.

- metallurgical control/silver accounting across the plant

- control of the process equipment for optimal performance.

### 17.8.1 METALLURGICAL CONTROL/SILVER ACCOUNTING

Metallurgical control of the process plant will be achieved by sampling of the head, tail, and intermediate streams at appropriate locations. A summary of the proposed sampling locations and methods are provided in the following sub-sections.

#### *MILLING CIRCUIT*

The amount of silver input to the milling circuit will be calculated from the mass of ore, as measured by an electromechanical belt weightometer, and the feed head grade will be determined by periodic stop belt sampling of the ball mill feed conveyor.

The amount of silver output from the milling circuit will be calculated from the pulp density, flow rate, and silver grade of the cyclone overflow, determined by periodic sampling and assaying of the cyclone overflow.

#### *GRAVITY AND INTENSIVE LEACH CIRCUIT*

The amount of silver entering the gravity circuit will be calculated by sampling the gravity circuit feed (slurry sampling of the second cyclone underflow stream) for pulp density, flow rate, and silver grade.

The pregnant solution leaving the intensive leach reactor will be sampled periodically in order to determine the solution silver tenor. The solution flow rates of these streams will be recorded by in-line monitors and used in conjunction with the solution tenner in order to determine the silver recovered from the gravity circuit.

#### *LEACH AND DEWATERING CIRCUIT*

The amount of silver input and output from the leach and dewatering circuits will be calculated from the pulp density, flow rate, and silver grade (solids and solution assays) measurements at input, output and appropriate intermediate streams. These parameters will be measured in a similar way as described in cyclone overflow sampling.

#### *ELECTROWINNING CIRCUIT*

The pregnant solution entering the electrowining circuit and the depleted solution leaving the electrowinning circuit will be sampled periodically, along with the electrowinning powder discharged, in order to determine the silver entering and exiting the circuit. In-line monitors will record the solution flow rates of these streams. From these results the silver recovered from the electrowinning circuit will be determined.

### 17.8.2 PROCESS EQUIPMENT CONTROL

The process equipment control philosophy has been developed to achieve the following objectives:

- maximize the mill throughput and stabilize the control of product particle size
- provide better control of the grinding circuits by control of the cyclone feed density
- control of mill dewatering cyclone underflow density to maintain leach efficiency
- monitor and control the electrowinning circuit to increase the Electrowinning efficiency and reduce soluble silver losses.

A detailed explanation of process equipment control can be found in Section 18.0.

# 18.0 PROJECT INFRASTRUCTURE

## 18.1 OVERVIEW

The Project will require the development of a number of infrastructure components. The locations of project facilities and other infrastructure items were selected to take advantage of local topography, accommodate environmental considerations, and to ensure efficient and convenient operation of the mine haul fleet.

Project infrastructure will include:

- airstrip
- off-site, on-site, and service road access
- mine haul roads
- TMF
- WRD and overburden dump
- ROM pad and crushed ore stockpile
- camp flood protection berms
- borehole water supply and distribution system
- water treatment and distribution
- sewage collection and management
- surface water management
- process and ancillary facilities, including:
  - process plant
  - crushing facility
  - reagent storage and handling
  - facilities for administration and an assay laboratory
  - heavy and light vehicle workshops
  - fuel storage and distribution
  - explosives storage and handling
  - emergency helipad
  - camp accommodation
  - mess and laundry facilities
  - medical centre
- power supply and local distribution network
- communications infrastructure.

## 18.2 LOGISTICAL INFRASTRUCTURE

The remote location of the mine site and the seasonal availability of the main mine access route prioritises the logistical infrastructure in order to keep the mine supplied with goods and personnel for uninterrupted operation. Supplies and equipment will be consolidated in Yakutsk and the regional ports, before being transported to site during the three to four months that the winter road is open. For nine months of the year, air travel is the only reliable transport to site. This poses a logistical issue, as the size of airplane permitted does not have the capacity to carry bulk supplies. Therefore, a minimum nine-month supply of goods, spares, and consumables needs to be transported to site during the limited three to four month window that the access road is open. Enough warehousing and storage also needs to be provided throughout the supply chain and on site to accommodate a nine-month supply.

### 18.2.1 PORTS

The Batamai Port on the Lena River is located approximately 370 km south of the Project area and can be accessed via the winter road. The port can accommodate boats and barges of up to 3,300 t, and it has a ferry link to the southern shore of the Lena River, which is navigable from mid-April until late September. The ferry has a 20-t capacity.

As part of the logistics supply line, a Batamai Port upgrade to provide a fuel reloading facility, by means of 500-$m^3$ plastic tanks, and provision of an open laydown area as a summer storage and holding facility, will enable containerised consumables such as reagents, along with fuel, to be stockpiled during the summer months for haulage along the winter road. This will reduce the current haulage distance of 570 km to 370 km, and reduce turnaround time from approximately six days to three days. The Batamai Port is located on the northern bank of the Lena River; trucks bringing goods to site from the Batamai Port will not have to wait for the Lena River to freeze, which extends the transport window.

### 18.2.2 RAIL

Yakutsk is served by the Amur-Yakutsk Mainline, a branch line off the Trans-Siberian Railway from Bamovskaya Station near Skovorodino in Amur Oblast. The rail line provides the opportunity for overland transport of equipment and supplies from the deep sea port of Vladivostok to the east, and from rail links to the Black Sea ports to the west.

There are a number of freight handling companies operating Trans-Siberian rail cars transporting containerised freight, as well as loose bulk, machinery, and perishable items, providing an alternative overland transport route for construction and operational equipment and supplies.

### 18.2.3 ACCESS ROADS

The area is serviced by a number of public winter roads serving villages on route to site. The closest road in the vicinity of the mine site camp is used by reindeer herders during migration, which will temporarily increase traffic. Extra care on the part of drivers will be required during the migration period and some temporary hold up may

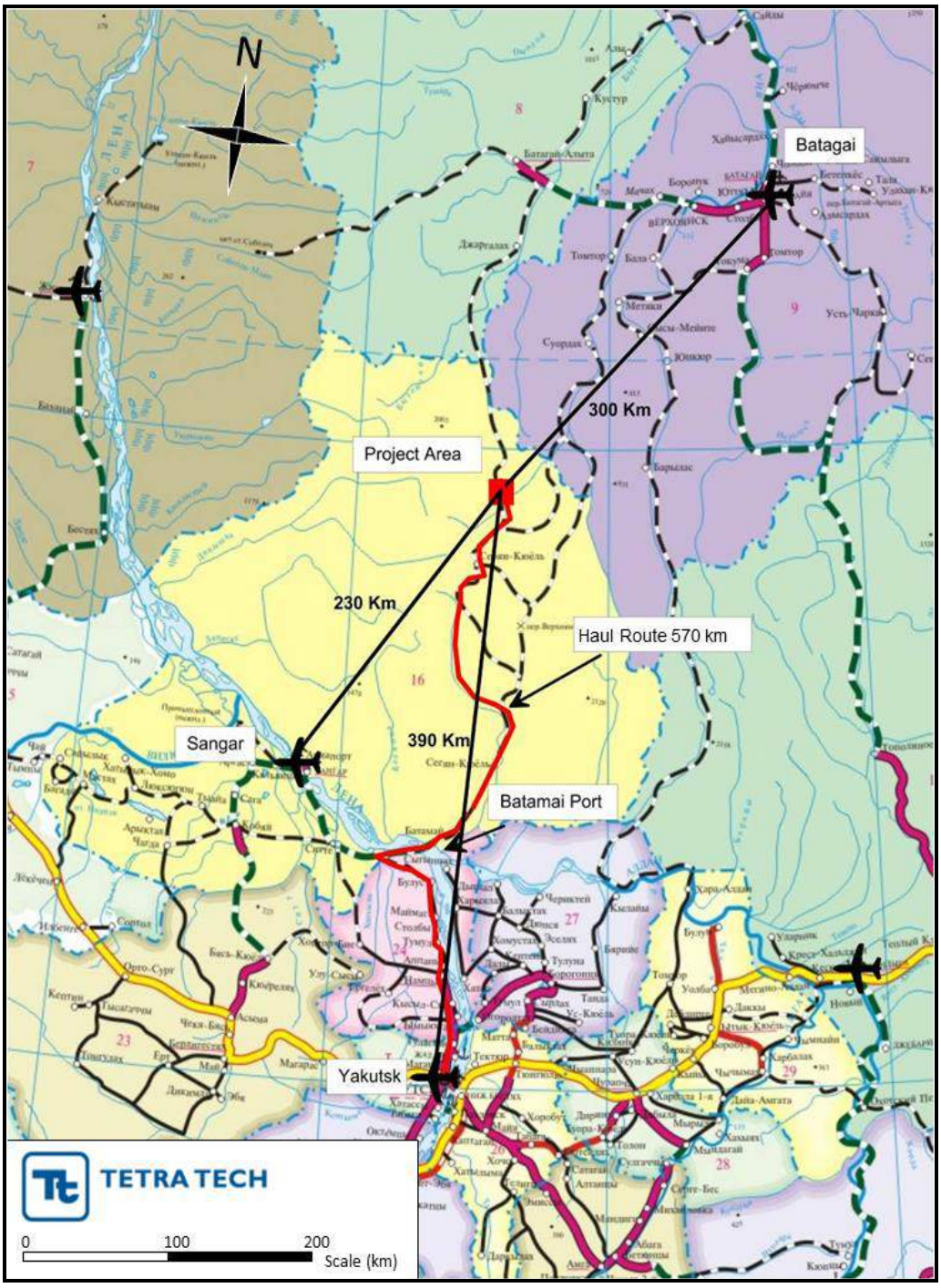
be experienced. The winter roads are usable between mid-December and mid-April (varying from year to year).

The local Sakha authority is responsible for determining when the road is open, and granting permission for the road to be used. Early in the season (20th December) the road opens with a 5-t weight limit and, as the ice thickens, weight limits are raised to 10 t for the official opening on 1st January, and finally 20 t from 15th January to 15th April, although heavier loads can be transported by special arrangement. For general site deliveries, a size limit of 12 m (a 40-ft container) and a load weight limit of 14 t is recommended before special measures are taken.

The current haulage route is shown in Figure 18.1. The total distance by road from Yakutsk to the Property is 570 km. Based on the last five years of moving consumables and heavy equipment to site, a one-way trip takes, on average, two days. The 200-km leg from Yakutsk to Batamai takes eight hours and the remainder of the two days is used to negotiate the more remote section of road between Batamai and the mine site. Generally, the roads are in better condition later in the season and shorter journey times can be expected. Conversely, early season journeys between Yakutsk and the mine site during December and January can take longer than two days. For safety, several trucks will travel in a convoy to ensure assistance is available in the event of a breakdown, accident, or a truck getting stuck.

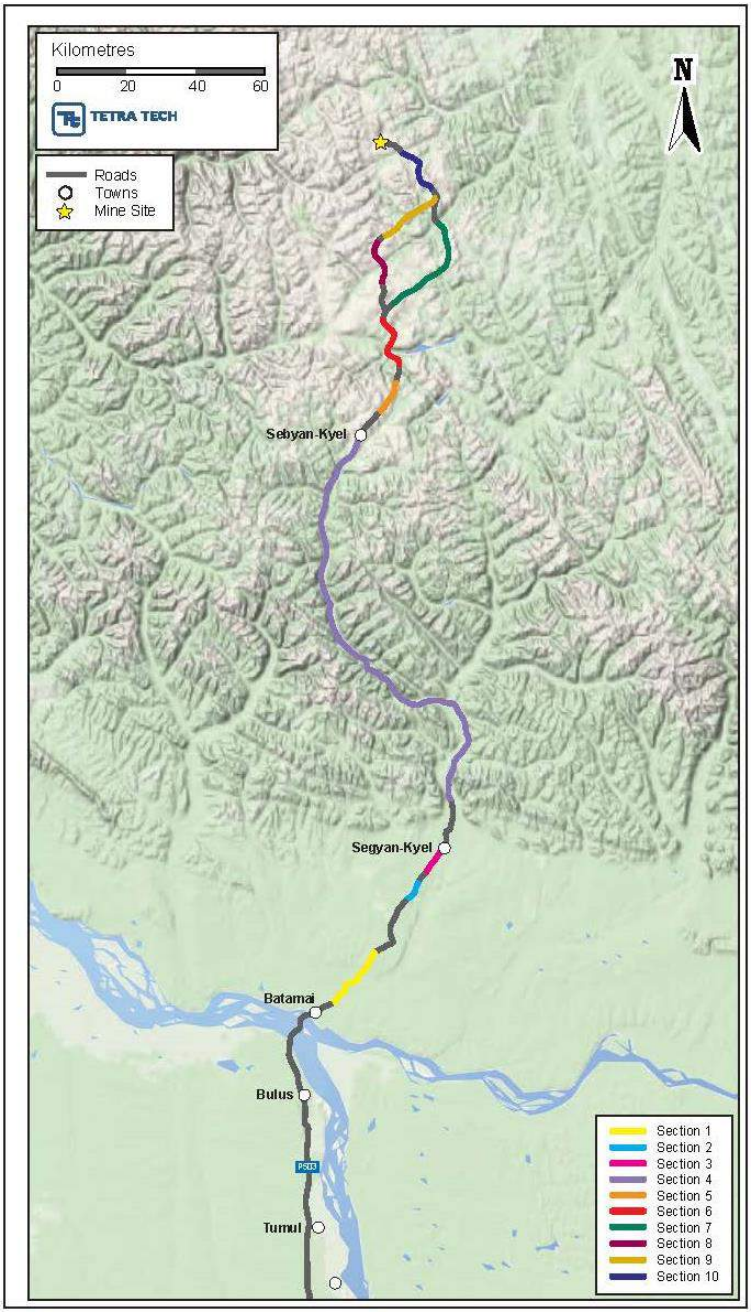
The main obstacles on the route to site are snow, boulders, and fallen trees, which can make driving difficult. Small unfrozen rivers also allow water to flood the ice in some sections between Batamai and site (Figure 18.2).

**Figure 18.1 Transport Routes**




Note: Red outline = project area; black lines = existing gravel roads

**Figure 18.2 Winter Road**




Notes:

| Road Section | Typical Terrain |
|---|---|
| 1 | Narrow forest road with sharp turns |
| 2 | Steep mountainous road |
| 3 | Swampy road with pigweed |
| 4 | Overflow ice, steep river entry and exit. |
| 5 | Steep mountainous road |
| 6 | Overflow ice, steep river entry and exit. |
| 7 | Overflow ice, steep river entry and exit. |
| 8 | Overflow ice, steep river entry and exit. |
| 9 | Overflow ice, steep river entry and exit. |
| 10 | Overflow ice, steep river entry and exit. |

Road maintenance is carried out by specialist contractors under the direction of Prognoz, with the maintenance burden increasing in line with road usage. Typically, contractors will maintain the road with a front-end loader, accompanied by a fuel truck, to complete sections of the road without the need to ferry fuel back and forth. Maintenance begins in September to prepare for the official opening of the road on 1st January. Prognoz structure their maintenance around the requirements of truck movements and the burden increases during severe conditions, or after a big flood season. From December to April, a one-way road clearing trip takes approximately two weeks, depending on weather conditions.

Historically, Silver Bear has moved up to 50-t payloads on the winter road for one off special loads, such as a Caterpillar D9 bulldozer. For the 2015/2016 winter road season, the road was upgraded to provide a reliable route for process equipment delivery, in addition to regular bulk deliveries of construction material, spares, and consumables. The tonnages transported to site over the last five years along the winter road are shown in Table 18.1.

**Table 18.1 Winter Road Transportation Tonnages**

| Year | Winter Road Transportation Tonnages (t) |
|---|---|
| 2011 | 700 |
| 2012 | 2,000 |
| 2013 | 200 |
| 2014 | 200 |
| 2015 | 2,800 |

The 2015/2016 winter road season transported the normal camp and exploration consumables, equipment, and construction material and consumables. As would be expected during construction, the bulk of the 3,883 t of construction material is made up of structural steel, cement, and rebar, accounting for 3,000 t of material required to be transported. A summary of the winter road transport statistics is provided in Table 18.2, Table 18.3, and Figure 18.3.

**Table 18.2 Winter Road Transportation Load Tonnages 2015/2016 by Item**

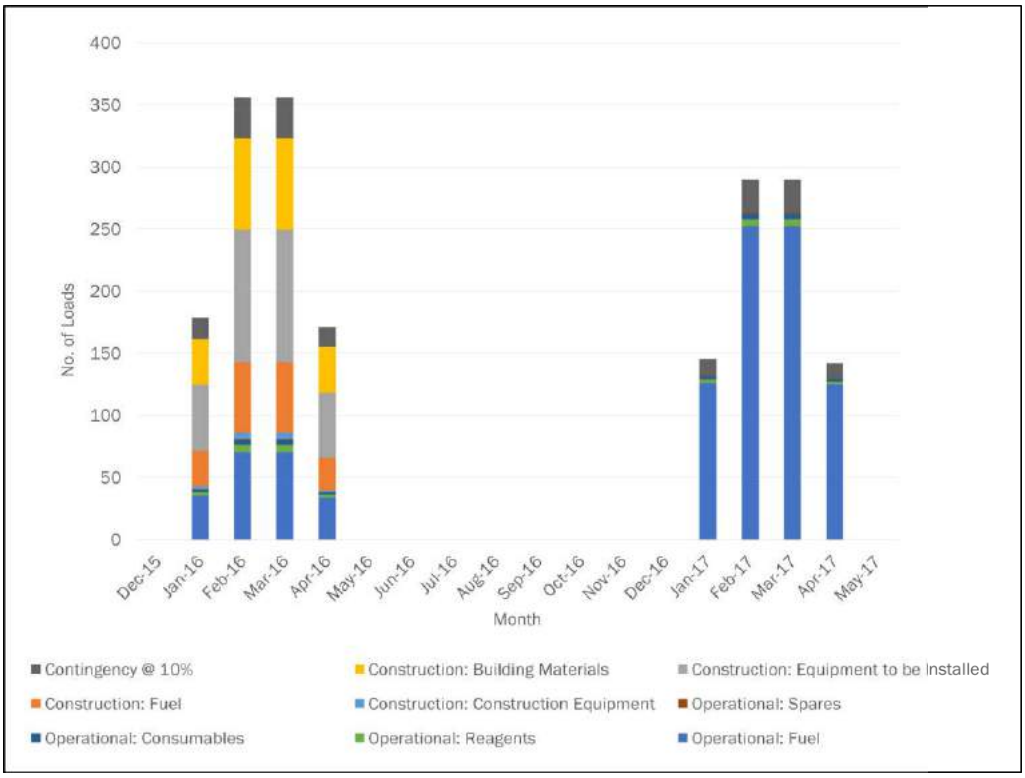
| Item | 2015/2016 Winter Road Season Loads (t) |
|---|---|
| Mechanical Equipment | 507 |
| Electrical and Control Equipment | 310 |
| Piping | 63 |
| Valves | 3 |
| Structural Steel | 1300 |
| Cement and Rebar | 1700 |
| **Total Construction Materials** | **3,883** |
| Liners | 2 |
| Grinding Balls | 20 |
| Lime | 20 |
| Sodium Cyanide | 100 |
| Flocculent | 1 |
| Fuel | 2,500 |
| Camp and Exploration Consumables | 2,800 |
| **Total Consumables** | **5,443** |
| **Total** | **9,326** |

During normal operation, fuel deliveries make up the bulk of the loads delivered to site, with typically just over 5,000 t making its way up the winter road to site in a season (Table 18.3).

**Table 18.3 Annual Winter Road Transportation Tonnages by Item**

| Item | Annual Winter Road Tonnages (t) |
|---|---|
| Mechanical Equipment | 515 |
| Electrical and Control Equipment | 435 |
| Piping | 8 |
| Valves | 15 |
| **Total Equipment** | **973** |
| Liners | 10 |
| Grinding Balls | 100 |
| Lime | 100 |
| Sodium Cyanide | 500 |
| Flocculent | 5 |
| Fuel | 5,050 |
| Camp and Exploration Consumables | 2,800 |
| **Total Consumables** | **8,565** |
| **Total** | **9,538** |

**Figure 18.3 Estimated Truck Loads to Site 2016/2017**




Source: Tetra Tech

Access from Batamai to the north via winter road has been possible historically; however, during the last 20 years the road has had no funding and had run into disrepair. The road could be used in exceptional circumstances.

## 18.3 SITE LAYOUT

The site layout shown in Figure 18.4, displays the location and orientation of the three main mine site components:

- the Vertikalny open pit area and underground mine
- the process plant facility
- the supporting site infrastructure, which encompasses all roads, buildings, facilities, and structures that support—but do not directly contribute to—the primary purpose of the mining operation.

Site preparation will consist of clearing overburden, and grubbing of areas that will accommodate the surface facilities.

### 18.3.1 SITE LAYOUT DESIGN BASIS

Silver Bear sought to establish mine site facilities in the immediate vicinity of the main Vertikalny deposit. The layout of the facilities on site was optimized and several concepts were analysed before arriving at the final design, shown in Figure 18.4.

The mine site layout design philosophy was to keep the mine site as compact as is practical (in order to minimise environmental and social impact), keep haul and pumping distances as short as possible, and minimise the amount of surface water that will have to be managed as a result of infrastructure interference.

The area available for mine development around the deposit is heavily constrained; a hilly terrain, with steep slopes, within a large licence area. The mine site layout design has been constrained by:

- the Property licence area
- the Sirelendge River to the north and east of the mine site
- the topography of the mine site.

Local meteorological conditions, as well as the location of equipment, buildings, and storm drainage, were taken into consideration during the site layout design. The process plant is set on the hill top at the closest suitable location to the pit to minimise haul distances, and is oriented to take into account the prevailing wind direction. The prevailing winds recorded on an annual basis show the dominant directions are northeast and southwest.

The plant site layout, shown in Figure 18.5, is based on the concepts of maximised operability, maintainability, and general safety. Special design attention was given to the positioning of process and other equipment in the plant layout to ensure direct and efficient flow of material from the ROM feed point, through to the silver powder production room, minimising conveyor lengths and piping runs.

**Figure 18.4 Site Infrastructure Layout**

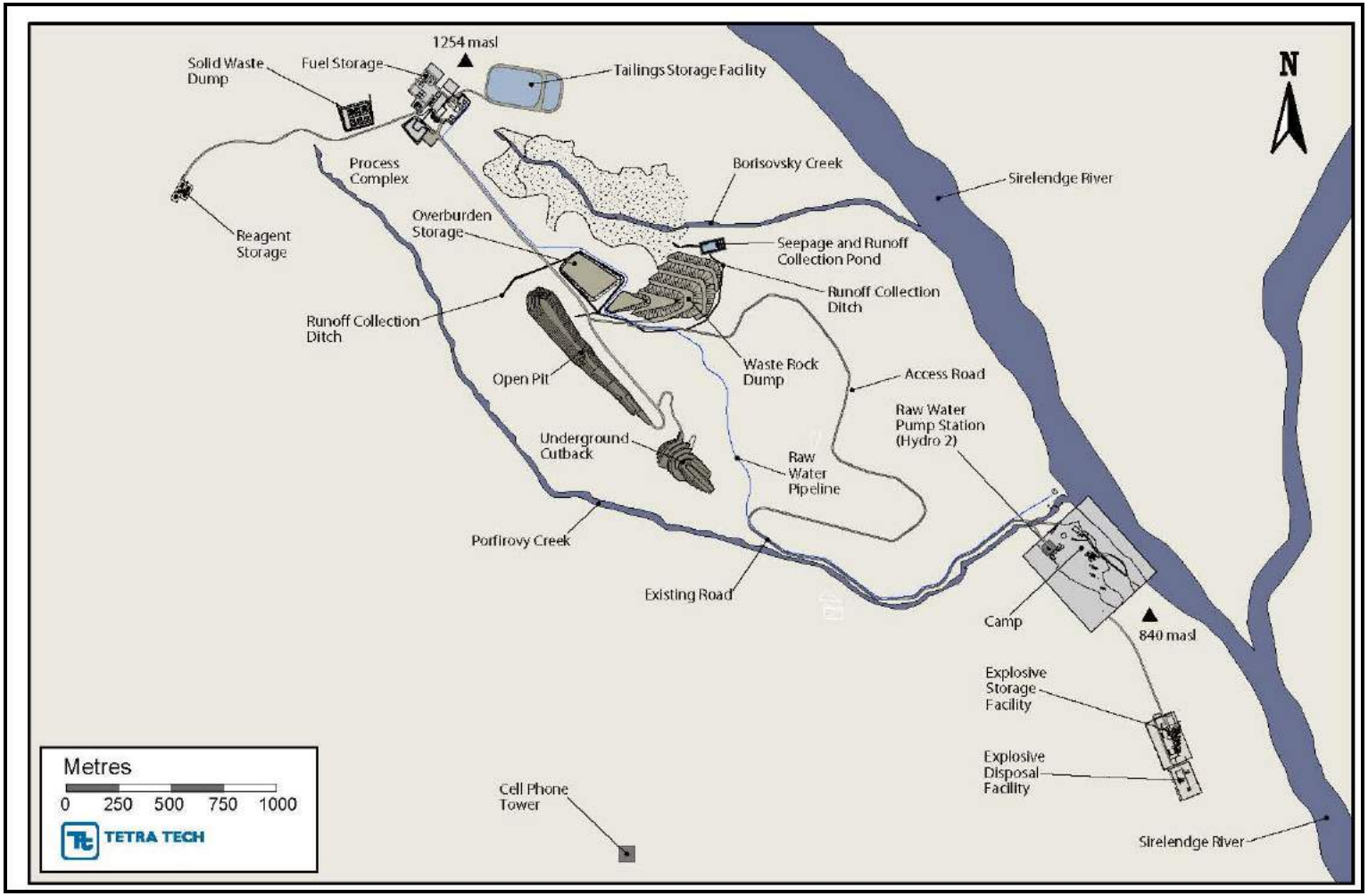
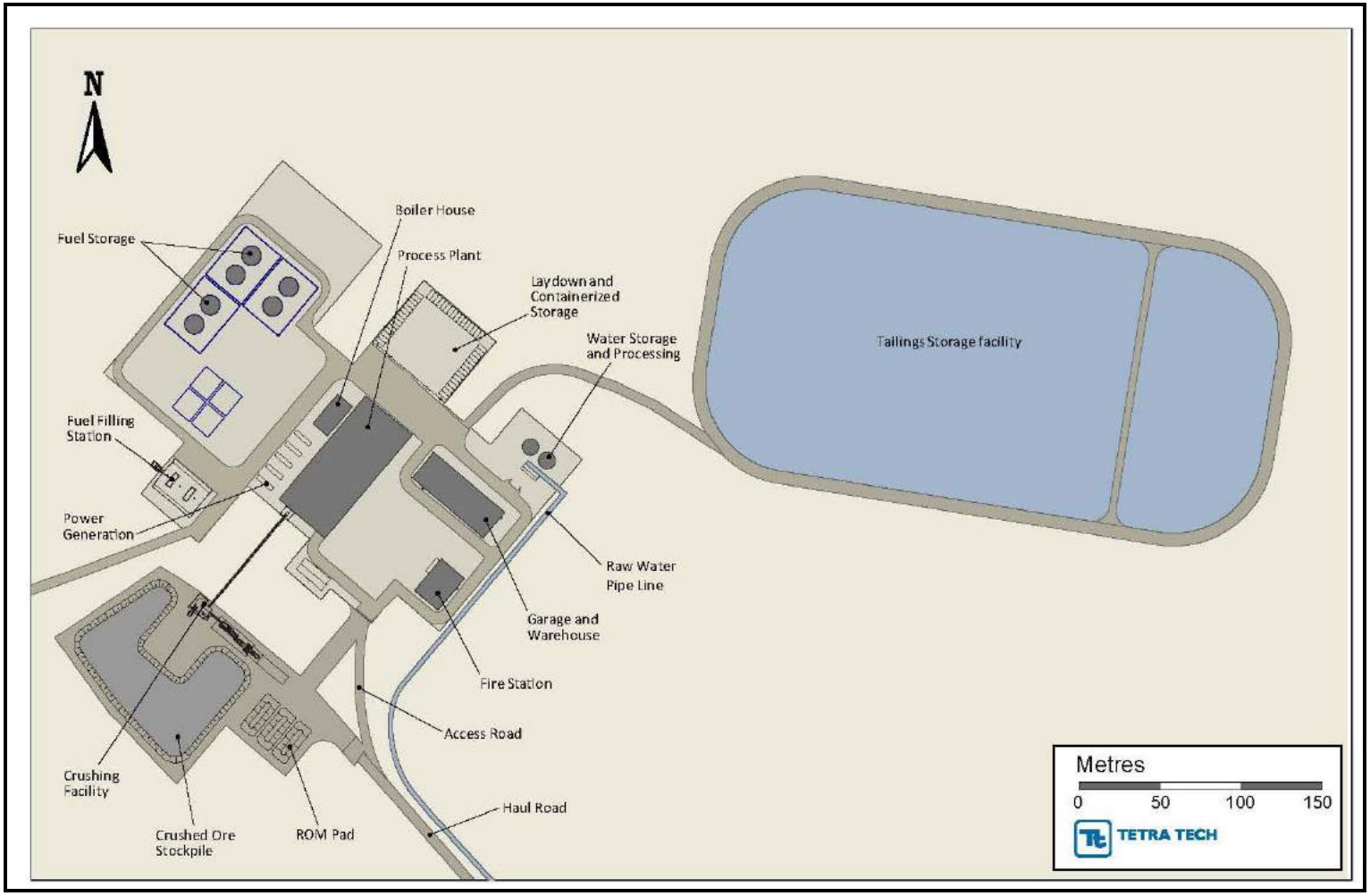


**Figure 18.5 Process Plant Facility Layout**



## 18.4 SITE GEOTECHNICAL

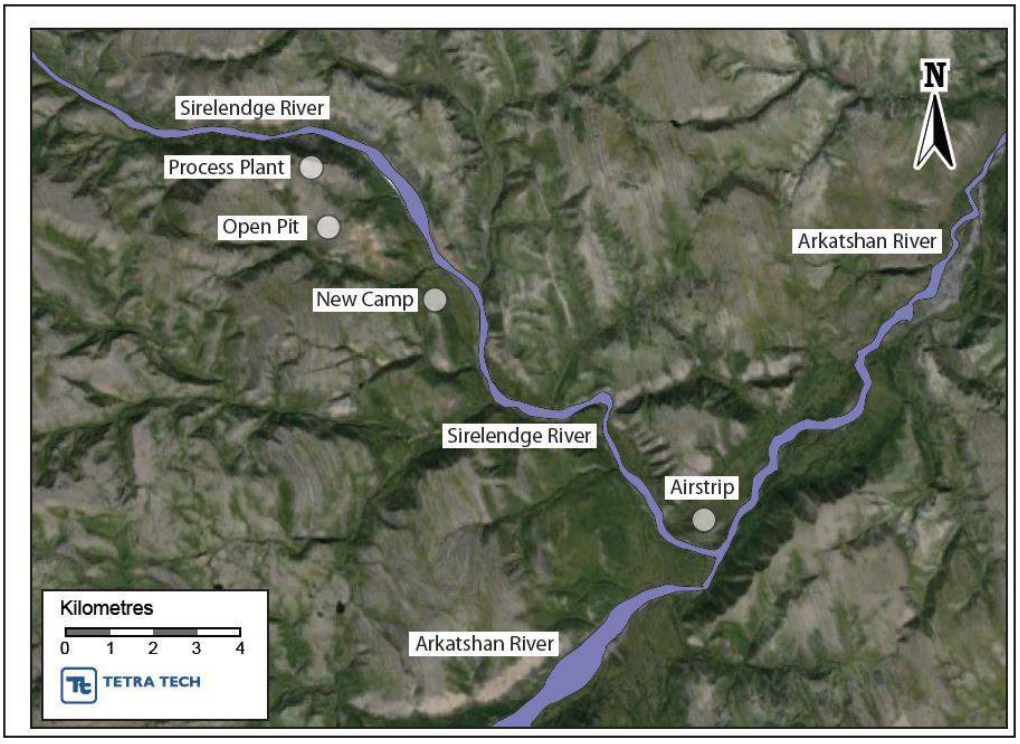
The Project infrastructure will be spread across three distinctly different areas, located along two river valleys, the Sirelendge and the Arkatshan, as shown in Figure 18.6.

The three areas are:

- the old camp site and airstrip
- the new camp area with storage facilities
- the central part of the Project, which will include the process plant, auxiliary buildings, and the dry stack TMF.

The three individual areas are located at three different elevations, in relation to the river levels in the two valleys. Therefore, they present somewhat different geotechnical features and conditions for the design and construction of buildings, roads, berms, pipelines, etc. The following subsections summarize the general soil conditions across the three areas.

**Figure 18.6 General Plan Showing the Mine Site Area, Airstrip, and Area River Valleys**




### 18.4.1 OLD CAMP SITE AND AIRSTRIP

The historic camp site and airstrip are located at the junction of the two major rivers in the area, as shown on Figure 18.6. The river valley floors are generally covered with permeable, well-sorted rock fragments, comprising sand to boulder sized soil grains. Smaller particles, such as clay and silt, have also been transported by the rivers and deposited at their junction, forming the floodplain. The subgrade of the

airstrip, located on that floodplain, generally comprises a cobble- and boulder-like rock fragment matrix, with sand, silt, and clay filling the voids of the coarse granular mass (Figure 18.7 and Figure 18.8).

**Figure 18.7 Surface Soil Conditions across the Airstrip and along the Road to the Mine Site**

**Figure 18.8 Bank of the Sirelendge River Next to the Airstrip**

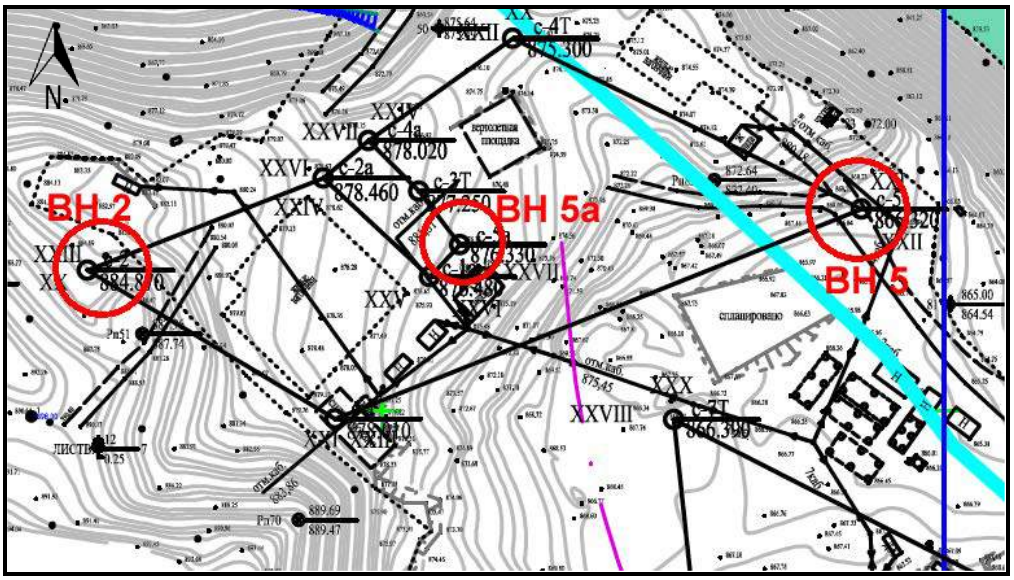
Note: Figure shows gravel, cobbles and boulders along the bank of the Sirelendge River next to the airstrip, with some silt and sand in the voids of the generally coarse-grained granular soil matrix

### 18.4.2 New Camp Site and Storage Areas

The new camp site is located on an elevated plateau, at the junction of the Sirelendge River and the Porfirovy Valley, as shown in Figure 18.4. The average elevation of the camp site is located approximately 40 m above the adjacent Sirelendge Valley, while the surface of the storage area is located at a somewhat lower elevation, approximately 25 m above the adjacent river level.

As part of an extensive geotechnical investigation, a large number of test holes were drilled/excavated in the new camp and storage areas by a local company (named ООО "НСИ" (NCI)), in order to evaluate the general soil conditions across the site. A detailed geotechnical report (NCI 2016) was completed by NCI, summarizing the thicknesses and properties of the soil overburden across the Property. A copy of that report can be found in Appendix I. A section of the relevant test-hole map for the camp and storage areas is shown in Figure 18.9. The location of three representative test holes (BH 2, BH 5 and BH 5a) are marked with red circles on the figure. A transcript from the NCI (2016) report is shown in Table 18.4, which presents data in connection with the thicknesses and conditions of the soil and rock strata in the area.

**Figure 18.9 Representative Geotechnical Test Locations across the New Camp Site and Storage Areas**




Note: BH – borehole

**Table 18.4 Recent Geotechnical Investigation Field Notes, Presenting the Intercepted Layers at Three Representative Test Locations at the Camp Site**

| Borehole No. | Thickness (m) | Depth (m) | Description |
|---|---|---|---|
| 2 | 1.0 | 1.0 | Shingle soil with up to 25% grey sand aggregate, loosely frozen, marginally water-saturated when thawed. The detrital material is represented by sedimentary rocks of average durability, of poor degree of roundness. |
| 2 | 2.1 | 3.1 | Transparent ice, thick, with sand and organic residues of 10 to 15%. From 2.4 m depth ice is porous, mouldy, and free of impurities. |
| 2 | 1.4 | 4.5 | Gravel soil with up to 37% grey sand aggregate, frozen, of crusted cryogenic texture. Visible ice content ≈0.1 unit fractions, water-saturated when thawed. The detrital material is represented by sedimentary rocks of average durability, of poor and average degree of roundness. |
| 2 | 1.0 | 5.5 | Transparent ice, thick, with sand and organic residues of 10 to 15%. From 2.4 m depth ice is porous, mouldy, and free of impurities. |

*table continues…*

| Borehole No. | Thickness (m) | Depth (m) | Description |
|---|---|---|---|
| 2 | 1.4 | 6.9 | Gravel soil with up to 20% grey sand aggregate, frozen, frozen, of crusted cryogenic texture. Visible ice content ≈0.1 unit fractions, water-saturated when thawed. The detrital material is represented by sedimentary rocks of average durability, of poor and average degree of roundness. |
| 2 | 8.1 | 15 | Shingle soil with up to 14% grey sandy loam aggregate, frozen, frozen, of crusted cryogenic texture. Visible ice content ≈0.2 unit fractions, water-saturated when thawed. The detrital material is represented by sedimentary rocks, of average durability, of poor to average degree of roundness. |
| 2 | - | - | Ground water was not encountered during drilling. |
| 5 | 5.4 | 5.4 | Shingle soil with up to 35% sandy loam aggregate, frozen, of massive and crusted cryogenic texture. Visible ice content <0.1 unit fractions, the aggregate is plastic when thawed, from 2.0 m depth soil is of crusted cryogenic texture Λв≈0.1 to 0.2 unit fractions, the aggregate is fluid when thawed. The detrital material is represented by sandstones and siltstones of average durability and durable, of poor to good degree of roundness. |
| 5 | 1.6 | 7.0 | Medium sized sand, grey, frozen, of massive cryogenic texture moderately water-saturated when thawed. |
| 5 | 2.2 | 9.2 | Shingle soil with up to 20 to 25% sand aggregate, frozen, of crusted cryogenic texture. Visible ice content ≈0.1 to 0.2 unit fractions, water-saturated when thawed. The detrital material is represented by sedimentary rocks, of average durability and durable, of poor to good degree of roundness. |
| 5 | 1.8 | 11 | Gravel soil with up to 20% sand aggregate, frozen, of crusted cryogenic texture. Visible ice content ≈0.1 to 0.2 unit fractions, water-saturated when thawed. The detrital material is represented by sedimentary rocks, of average durability and durable, of poor to good degree of roundness. |
| 5 | 4.0 | 15.0 | Shingle soil with up to 20% sandy loam aggregate, frozen, of crusted cryogenic texture. Visible ice content <0.1 unit fractions moderately water-saturated when thawed. The detrital material is represented by sedimentary rocks of average durability and durable, of poor to good degree of roundness. |
| 5 | - | - | Ground water was not encountered during drilling. |
| 5a | 3.1 | 3.1 | Shingle soil with up to 15% brown sand aggregate, frozen, of massive cryogenic texture, from 2.3 m depth of crusted cryogenic texture Λв≈0.1 unit fractions, marginally water-saturated when thawed. The detrital material is represented by sandstone of average durability, of average and good degree of roundness. |
| 5a | 4.9 | 8.0 | Gravel soil with up to 20 to 25% brown sand aggregate, frozen, of crusted cryogenic texture. Visible ice content ≈0.1 to 0.2 unit fractions, water-saturated when thawed. The detrital material is represented by sandstone of average durability, of good to poor degree of roundness. |
| 5a | - | - | Ground water was not encountered during drilling. |

Based on information obtained from Table 18.4, it is evident that the ground conditions on the camp's plateau are represented by an undulating bedrock profile, with weathered rock overburden generally covering the entire area. Pockets of peat and ice were also intercepted in some poorly drained areas within the soil deposits. For example, an ice pocket as large as 2.1 m was intercepted at test hole no. 2, at the extreme west end of the camp site.

Construction of the already erected camp and storage buildings required the removal of peat and ice pockets, and the spreading of cobble- and boulder-like fill, in order to provide appropriate subgrade for the buildings' foundations. It is assumed that all peat and ice was removed from beneath all existing structures, wherever those pockets were intercepted (Figure 18.10).

Pockets of black peat with large tree remains were also noted in some low-lying areas between the storage and new camp area.

**Figure 18.10 Soil Conditions across the Storage Areas**

### 18.4.3 Process Plant and TMF Areas

As shown in Figure 18.4, the process plant, the dry stack TMF, and all related structures are proposed for construction across the northern most part of the mine site, on the top of the mountain. The area selected for these structures is generally flat, with gentle slopes leading toward the edges of the plateau, where the surface then drops sharply into the adjacent valleys. The elevation difference between the plant site and the nearby Sirelendge Valley is approximately 400 m.

The soil conditions across the plant and TMF areas are generally represented by weathered rock overburden over shallow bedrock. Based on the reported test results

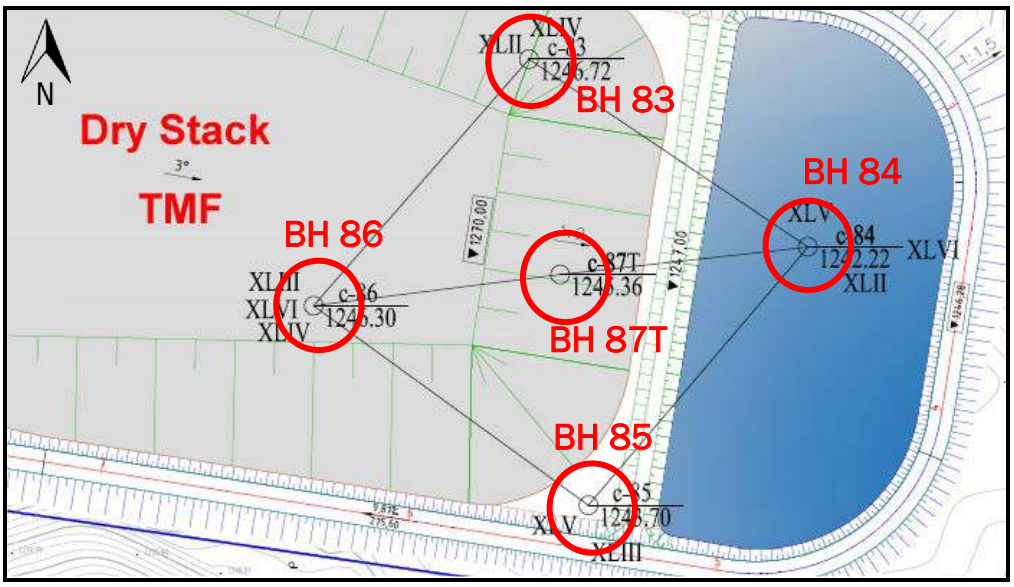
(NCI 2016), the area of the proposed dry stack TMF is covered with shallow weathered rock fragments, down to depths of between 1.2 and 1.5 m, overlying siltstone bedrock.

Beneath the weathered rock, comprising silt-sand-gravel and cobble-sized particles, the underlying rocks may also be fractured/jointed. However, these fractures and joints are the result of the tectonic history of the landform and not the result of the weathering process. Tectonic history is the sequence of earth movements that have brought about the gross arrangement and relative elevation of major topographic elements like mountains. Joints (also termed extensional fractures) are planes of separation within rock masses, on which no shear displacement had taken place. The two walls of the resulting opening in such rock masses typically remain in relatively tight contact. Joints may also result from regional tectonics, faulting, or internal stress release during uplift from lower elevations.

Based on the borehole results from the plant area, the opening of the joints in the permanently frozen sandstone and siltstone rocks varied between 0.5 mm and 3 mm only. During tectonic history of the mountain, water may have percolated down into these cracks and joints within the rock mass, and that water froze when permafrost was formed in the area, without changing the volume of the rock mass. This had been confirmed by the fact that after thawing the ice, found in the joints in the boreholes, the samples were not fully saturated.

The approximate locations of the above mentioned test holes at the process plant and TMF areas are shown on Figure 18.11, and the information obtained during the recent geotechnical investigation, is presented in Table 18.5.

**Figure 18.11 Borehole Locations in the Area of the TMF**




Note: Figure is not to scale

**Table 18.5 Recent Geotechnical Investigation Field Notes, Presenting the Intercepted Layers at Representative Test Locations at the Proposed Dry Stack TMF Site**

| Borehole No. | Layer Thickness (m) | Depth (m) | Description |
|---|---|---|---|
| 83 | 0 | 0.1 | Topsoil, frozen. |
| 83 | 1.4 | 1.5 | Gruss sandy loam, brown, frozen, of massive cryogenic texture, is plastic when thawed. The detrital material is represented, primarily, by siltstone of average durability. |
| 83 | 2.5 | 4 | Grey siltstone, of average durability, fractured very intensely, open-type fissures, 0.1 to 2 mm width, filled with ice and the frozen sandy loam, oriented at an angle 0 to 10° and 80 to 90° to the core axis, tile core recovery. |
| 83 | - | - | Ground water was not encountered during drilling. |
| 84 | 0.1 | 0.1 | Top soil, frozen. |
| 84 | 1.1 | 1.2 | Shingle soil with sandy loam aggregate up to 20%, frozen, of massive cryogenic texture, marginally water-saturated when thawed, from a depth of 0.8 m of crusted cryogenic texture. Visible ice content <0.1 unit fractions, moderately water-saturated when thawed. The detrital material is represented, primarily, by siltstone of average durability. |
| 84 | 2.8 | 4 | Grey siltstone, of average durability, fractured very intensely, open-type fissures, 0.1 to 2 mm width, filled with ice and frozen sandy loam, oriented at an angle 0 to 10° and 80 to 90° to the core axis, tile core recovery. |
| 84 | - | - | Ground water was not encountered during drilling. |
| 85 | 0.1 | 0.1 | Topsoil, frozen. |
| 85 | 1.4 | 1.5 | Shingle soil with sandy loam aggregate up to 20%, frozen, of massive cryogenic texture, soil marginally water-saturated when thawed, from a depth of 1.0 m of crusted cryogenic texture. Visible ice content <0.1 unit fractions, moderately water-saturated when thawed. The detrital material is represented, primarily, by siltstone of average durability. |
| 85 | 2.5 | 4 | Grey siltstone, of average durability, fractured very intensely, open-type fissures, 0.1 to 2 mm width, filled with ice and frozen sandy loam, oriented at an angle 0 to 10° and 80 to 90° to the core axis, tile core recovery. |
| 85 | - | - | Ground water was not encountered during drilling. |
| 86 | 0.1 | 0.1 | Topsoil, frozen. |
| 86 | 1.1 | 1.2 | Shingle soil with sandy loam aggregate up to 20%, frozen, of massive cryogenic texture, marginally water-saturated when thawed, from a depth of 0.8 m of crusted cryogenic texture. Visible ice content <0.1 unit fractions, moderately water-saturated when thawed. The detrital material is represented, primarily, by siltstone of average durability. |
| 86 | 2.8 | 4 | Grey siltstone, of average durability, fractured very intensely, open-type fissures, 0.1 to 2 mm width, filled with ice and the frozen sandy loam, oriented at an angle 0 to 10° and 80 to 90° to the core axis, tile core recovery. |
| 86 | - | - | Ground water was not encountered during drilling. |
| 87т | 0.1 | 0.1 | Topsoil, frozen. |

*table continues...*

| Borehole No. | Layer Thickness (m) | Depth (m) | Description |
|---|---|---|---|
| 87т | 1.3 | 1.4 | Shingle soil with sandy loam aggregate up to 20%, frozen, of massive cryogenic texture, marginally water-saturated when thawed, from a depth of 1.0 m of crusted cryogenic texture, Visible ice content<0,1 unit fractions, moderately water-saturated when thawed. The detrital material is represented, primarily, by siltstone of average durability. |
| 87т | 8.6 | 10 | Grey siltstone, of average durability, fractured very intensely, open-type fissures, 0.1- 2 mm, filled with ice, oriented at an angle 0 - 10° and 80 - 90 °to the core axis, rarer at an angle 20 - 30° to the core axis, tile core recovery, from a depth of 5.5 m fractured very intensely, fissure are orient, primarily, at an angle 80 - 90° to the core axis, rarer at an angle 0 - 10° to the core axis, tile and cylinder core recovery up to 20 cm. |
| 87т | - | - | Ground water was not encountered during drilling. |

Representative images of the weathered rock overburden are shown in Figure 18.12 and Figure 18.13. During a recent site visit, silt and clay were also visible within the voids of the larger gravel, cobble, and boulder sized weathered rock matrix. In addition to the silt and clay pockets, attention should also be given to the locations and extents of any ice lenses, intercepted within the soil overburden.

**Figure 18.12 Soil (Weathered Rock Fragments) Conditions across the Plant Site**

**Figure 18.13 General Soil Conditions (Shallow Weathered Rock) Across the Upper Plateau, Approximately 400 m above the Adjacent Sirelendge Valley**

### 18.4.4 CONCLUSIONS

Based on the available data and information in connection with the soil conditions across the Project area, it appears that the predominant soil deposit (overburden) on the site comprises sand- to boulder-sized solid grains (weathered rock fragments), with random silt- and clay-sized particles filling the voids near the surface, mostly at poorly drained localized areas, and in the floor of the Porfirovy and Borisovsky valleys.

The formation of such overburden layers, comprising soil-mixed rock fragments, is a direct result of the extensive physical weathering process within the active zone of permafrost. Physical weathering causes rocks to disintegrate in situ; meaning the rock masses break up near their surfaces. Physical weathering occurs when there are changes in temperature over short periods of time. In permafrost areas, that temperature fluctuation happens within the so-called active layer, near the ground surface only. Two potential geotechnical related risks may be identified on this site:

- Organically contaminated, compressible soils (peat):
  - Peat pockets were intercepted in low-lying, poorly drained areas (in parts of the new camp site, for example), where decomposition of vegetation may have resulted in development of peat pockets. Since most of the buildings at the camp site have already been constructed, it can be assumed that their foundations are not sitting on peat deposits. It is recommended to remove all peat pockets (if encountered) from under all engineered structures (buildings, berms, dams, etc.), proposed to be built on the site.
  - Based on field notes from site personnel and observations during a site visit, it appears that such peaty areas have not been encountered across the upper plateau, where most of the critical infrastructure

components (process plant and dry stack TMF) are planned for construction.

- Large ice pockets within the soil overburden:
  - These pockets represent the highest risk to the stability and integrity of any structure built in permafrost areas. Thawing of potential ice pockets within the soil overburden in the future may result in serious damage to any building, even to rigid structures. It will be imperative during the construction phase that no ice pockets in soils are left in place beneath any engineered structures (buildings and dams). The simplest method for dealing with such situations is to remove all thaw-unstable silty and clayey soils (including potential ice pockets) from under critical structures, and establish their foundations on solid, well-drained rock, or thaw-stable dense, granular soils without any possibility of future frost heave or thaw damage to the substructures or dams.

The word permafrost means permanently frozen ground (soil and rock). It indicates a thermal condition where the temperature of the rock and soil of the upper part of the earth's crust remains below freezing throughout the year. Approximately 50% of the world's permanently frozen ground is located in Russia/Siberia. Permafrost may extend several hundred meters below the so-called active layer, and can be continuous and discontinuous. The approximate thickness of the permanently frozen ground at the mine site is between 300 and 400 m.

Construction of building foundations or other engineered structures in these areas require specific knowledge regarding permafrost and specialized construction techniques. Disturbing thaw-unstable soils in permafrost areas may cause thaw, resulting in uneven foundation settlements and detrimental consequences for structures. Permafrost lies beneath the seasonal frost zone and remains frozen even throughout the summers. Seasonal frost develops over the winter and thaws in the summer. This "seasonal frost zone", located over permafrost, is called the active layer, as shown in Figure 18.14.

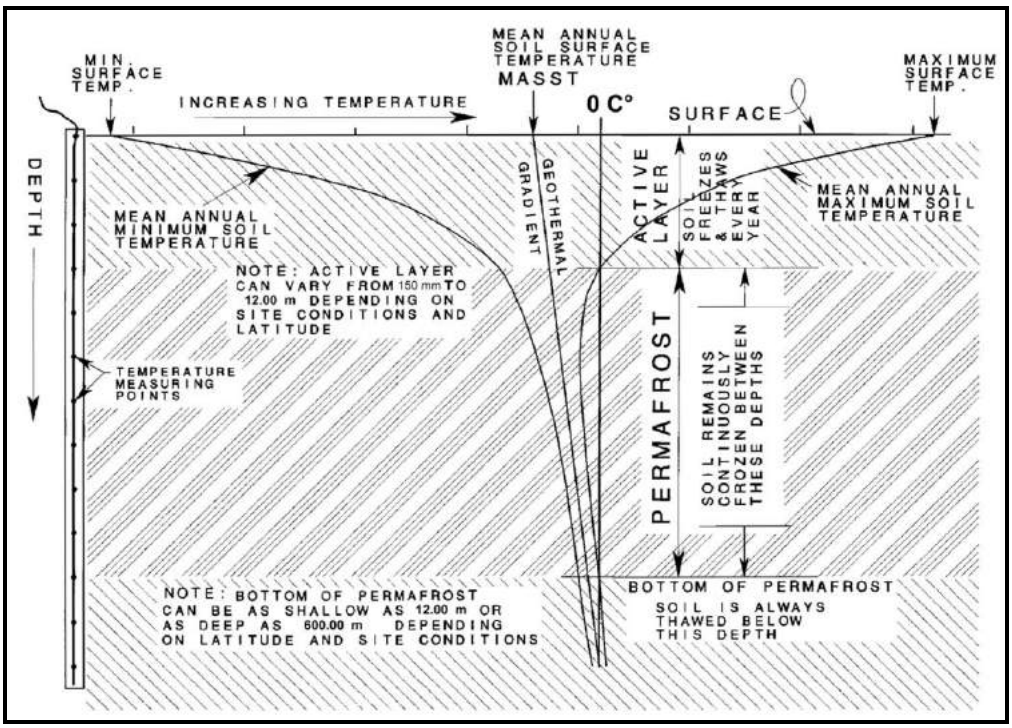
Field ground temperature measurements at the Project site prove that the active layer is less than 2-m thick across the entire Project area.

As pointed out previously, soil explorations were recently carried out across the site (NCI 2016) and a copy of the report can be found in Appendix I. Based on available information, it appears that at the site of the most important structures (process plant and dry stack TMF), sandstone and siltstone bedrock are available as foundation subgrade at relatively shallow depth below grade, and no frost and heave related problems can be anticipated if all thaw-unstable silt and clay-contained soils are removed from beneath all proposed structures.

As a preliminary guide, spread footings for heavily loaded structures will be established on bedrock, with consideration of an estimated bearing capacity value of 500 kPa, assuming that all foundation concrete is established on solid rock, which has been cleaned completely of all loose debris and shatter using an air hose or water jetting procedures. Structures may also be established on well-compacted engineered granular fill subgrade (crushed rock), with consideration of an estimated bearing capacity value of 150 kPa. As pointed out above, all peat, silt, and clay

contained soils and ice pockets must be completely removed from under all engineering structures, prior to construction.

**Figure 18.14 Ground Temperature Profile and Extent of Active Layer in Permafrost Areas**




## 18.5 DESIGN BASIS

### 18.5.1 STRUCTURAL DESIGN BASIS

#### *STRUCTURAL CLIMATIC LOADS*

Based on data received for the Project area (latitude 65.65° north and longitude 130.183° east), the climatic data for structural design are as follows.

#### *Wind*

The wind pressure at site corresponds to Zone III on the Wind Regions of USSR Map 3. As per SNiP (Russian Construction Codes and Regulations) 2.01.07-85 *Loads and Effects*, this corresponds to a wind pressure of $W_o$ = *0.38 kPa.*

The area type is assumed to be Type B, as per paragraph 6.5 of SNiP 2.01.07-85 *Loads and Effects*.

#### *Snow Load*

For the Project site, the snow load corresponds to Zone III on the Snow Regions of USSR Map 1A. As per Table 4 in SNiP 2.01.07-85 *Loads and Effects*, this corresponds to a snow pressure of $S_o$ = *1.0 kPa.*

### *Seismic*

The Project is located in an area with moderate seismic activity representing a medium earthquake hazard. The expected seismic intensity at the proposed mine site does not appear to exceed the Medvedev-Sponheur-Karnik (MSK) scale's VII Category, which has a ground acceleration between 0.8 and 1.6 m/s$^2$. Typically, MSK scale VII corresponds to a peak ground acceleration (PGA) of 0.1 g (i.e. 10% of gravity acceleration = 0.0981 m/s$^2$). As per the 2012 International Building Code (IBC), for a PGA of 0.1 g, the following seismic parameters can be obtained:

$S_S = 0.2\ g$

$S_1 = 0.1\ g$

Where:

$S_S$ = *0.2 s spectral response acceleration (5% damping), site Class B, and*

$S_1$ = *0.2 s spectral response acceleration (5% damping), site Class B.*

For further information on the seismic characteristics of the Project see Section 18.5.2

## *Structural Steel and Concrete*

### *Codes and Standards*

All structural designs shall be carried out in accordance with the latest revision of the following standards, regulations, specifications and codes:

- All applicable Russian codes and standards, or equivalent US, Canadian and European codes.
- Concrete, mortar, and grout shall conform to SP 52-101 2003 *Concrete and Reinforced Concrete Structures Without Pre-stressing*, and SP 52-105 2009 *Concrete Structures for Cold Climate and Permafrost Soils.*
- Reinforcement shall conform to GOST 5781-82 *Hot Rolled Steel for Reinforcement of Reinforced Concrete Structures,* welded wire mesh shall conform to GOST 23279-85 *Welded Mesh Reinforcement for Concrete Structures and Products, General Specifications.*
- Cement shall conform to GOST 7473 2010 *Cement Mixtures, Technical Specifications.*
- Masonry shall conform to SN 15.13330.2012 *Masonry and Reinforced Masonry Structures.*
- Structural steel shall conform to GOST 23118-2012 *Structural Steel Elements – General Specifications.*
- Welding shall conform to latest Russian welding standards.
- Galvanization shall conform to European Committee for Standardization codes as per: CEN/TC 262 *Metallic and Other Inorganic Coatings.*
- Painting shall conform to European Committee for Standardization codes as per: CEN/TC 139 *Paints and Varnishes*.

### UNITS

All notes, calculations, data instructions, dimensions on drawings, and specifications shall use metric units.

Materials and equipment shall all be specified in metric units. Where certain items are available in imperial sizes only, they shall be specified in metric units after soft conversion, with corresponding imperial sizes specified in brackets.

### DESIGN

Preliminary design will be carried out for reinforced concrete structures, foundations, structural steel supports, steel structures, access ways, and platforms. As much as possible, the structural steel shall be modularized so that construction work on site is minimized. Some of the buildings and structures include:

- process plant
- conveyor foundations
- pipe racks
- pre-engineered buildings.

### *Importance Category*

As per SNiP 2.01.07-85, the responsibility level of buildings and structures (classified accordingly to the economic, sociological, and ecological consequences for failure) for the Project shall be Level II, which is the normal responsibility level usually designated for industrial buildings.

### *Expansion Joints*

The maximum length of buildings and structures between expansion joints shall be 120 m.

### *Deflection*

Do not exceed the following deflection (D) to span (L) or height (H) ratios under live loads (Table 18.6 and Table 18.7).

**Table 18.6 Vertical D/L**

| Criteria | Value (D/L) |
|---|---|
| Crane Runway Beams | 1/800 |
| Floor Members | 1/360 |
| Roof Members Supporting Plaster | 1/360 |
| Roof Framing with Sheet Metal Cladding | 1/180 |

**Table 18.7 Lateral D/H**

| Criteria | Value (D/H) |
|---|---|
| Walls with Sheet Metal Cladding | 1/180 |
| Walls with Un-Insulated Cladding | 1/90 |
| Interior Walls with Permanent Partitions Subjected To 0.5 kN/m$^2$ Normal to the Walls:<br>With Brittle Finishes<br>With Flexible Finishes | <br><br>1/240<br>1/120 |
| Crane Runway Beams*<br>(Subject to Crane Lateral Force) | 1/600 |
| Building Column*<br>(Subject to Crane Lateral Force or Wind Force) | 1/300 |
| Building Frames<br>(Subject to Wind Forces) | 1/300 |
| *Follow manufacturers standards or the following additional crane runway tolerance criteria, whichever produces the most adverse effect: | |
| Maximum Permissible Tolerance Between Rail Centres | ±5 mm |
| Height Tolerance Between Rails<br>(S = Crane Span) | S/1000 |
| Permissible Height Tolerance Between Two Crane Rail Supports<br>(L = Distance Between Supports) | L/1500 |

Recommended depth (d) to span (L) ratios for steel beams and trusses are shown in Table 18.8.

**Table 18.8 Member Depths (d/L)**

| Criteria | Value (d/L) |
|---|---|
| Trusses | 1/14 |
| Equipment Support Beams* | 1/16 |
| General Platform Beams | 1/20 |
| Walkway Beams | 1/24 |

Note: *A deeper section may be required to avoid the beam resonating at the natural frequency of equipment.

### *Slab on Grade*

Slab on grade shall be constructed on engineered fill over suitable existing subgrade, approved by a geotechnical engineer unless noted otherwise.

Minimum thickness of slab on grade is shown in Table 18.9.

**Table 18.9 Minimum Slab on Grade**

| Criteria | Value (mm) |
|---|---|
| General Areas | 150 |
| Light Vehicular Traffic Areas | 200 |
| High Wheel Load Areas | 250 |

### *Live Loads/Imposed Floor Loads*

Minimum live/imposed loads are shown in Table 18.10.

**Table 18.10 Minimum Live Loads**

| Criteria | Value (kPa) |
|---|---|
| General Areas | 5.0 |
| Office Areas | 5.0 + Partition |
| MCC/Electrical Rooms | 15.0 |
| Mill Operating Floor | 15.0 |
| Laydown Areas | 12.0 |

Note: MCC – motor control centre

### *Roof Loads*

In addition to roof live loads, a collateral load of 0.75 kPa shall be allowed for the design of all building roofs unless noted otherwise.

## *MATERIALS SPECIFICATIONS*

### *Structural Steel*

Structural steel will conform to latest edition of Eurocodes shown in Table 18.11.

**Table 18.11 Structural Steel Eurocodes**

| Area | Code(s) |
|---|---|
| Hot Rolled Structural Steel<br>IPN, HP HD, HE/HL, IPE Shapes, UPN Channels and Steel Angles | Steel Grade S355 |
| Plates and Bars | Steel Grade S275 |
| Hollow Sections | Steel Grade S355 |
| Structural Pipes | Steel Grade S355 |
| Sag Rods and Pins | Steel Grade S275 |
| Bolted Connections | Grade 8.8 bolts |
| Welded Connections | As per EN ISO 2590<br>fy = 500 MPa |
| Anchor Colts | Grade 4.6 bolts |
| Floor Grating | 32 mm x 4.8 mm Welded Standard “Flowforge” type<br>Serrated grating : 38 mm x 4.8 mm |
| Trench Grating | 32 mm x 4.8 mm Welded Standard “Flowforge” type<br>Serrated grating: 38 mm x 4.8 mm |
| Checkered Plates | 8 mm minimum checker plate with raised pattern<br>6 mm minimum for lightly loaded area |
| Stair Treads | Grating tread with checker plate nosing 32 mm x 4.8 mm Welded Standard “Flowforge” type<br>Treads with serrated grating: 38 mm x 4.8 mm<br>Stair tread width – 308 mm |

*table continues...*

| Area | Code(s) |
|---|---|
| Railing and Handrails | 48.3 outer diameter by 4-mm thick wall round pipe for horizontal handrails, 48.3 outer diameter by 6-mm thick wall round pipe for all vertical handrail posts |
| Kick Plates | 150-mm high |

Note: For primary members subject to tensile fatigue stresses, and/or high-impact loads, and/or exposed to cold weather conditions, steel grade used shall be weldable, notch-tough grade.

### *Concrete*

Cement shall conform to EN 197 and use CEM I or CEM type II/A, unless noted otherwise. The Project will use corrosive resistant cement where applicable and sulphate resisting cement where applicable.

The specified compressive strength of concrete is shown in Table 18.12.

**Table 18.12 Concrete Specified Compressive Strength**

| Area | 28 Day Strength (MPa) | Maximum Aggregate (mm) | Water/Cement Ratio |
|---|---|---|---|
| Structural Concrete | 30 | 20 | 0.45<br>0.40 (corrosive) |
| Mass Foundation<br>(only if noted as such on the drawings) | 15 | 40 | 0.45<br>0.40 (corrosive) |
| Blinding Concrete<br>(only if noted as such on the drawings) | 15 | 20 | 0.45<br>0.40 (corrosive) |

### *Reinforcing Steel*

**Table 18.13 Reinforcing Steel**

| Area | Code |
|---|---|
| Deformed Type Billet Steel Bar | In conformance with GOST 5781-82 Grade A-111(A400)<br>fy = 390MPa |
| Welded Wire Fabric | In conformance with GOST 23279-85 |

### *Grout*

Normal grout shall be non-shrink, non-metallic, and non-corrosive cementitious grout. Epoxy-based, non-shrink grout shall be used under sensitive equipment only.

### *Masonry*

The Project will use modular metric size as per Russian codes. The minimum compressive strength of a hollow core concrete block unit shall be 15 MPa, and the compressive strength of masonry grout shall not be less than that of the concrete block used.

### 18.5.2 PROJECT SEISMIC CHARACTERISTICS

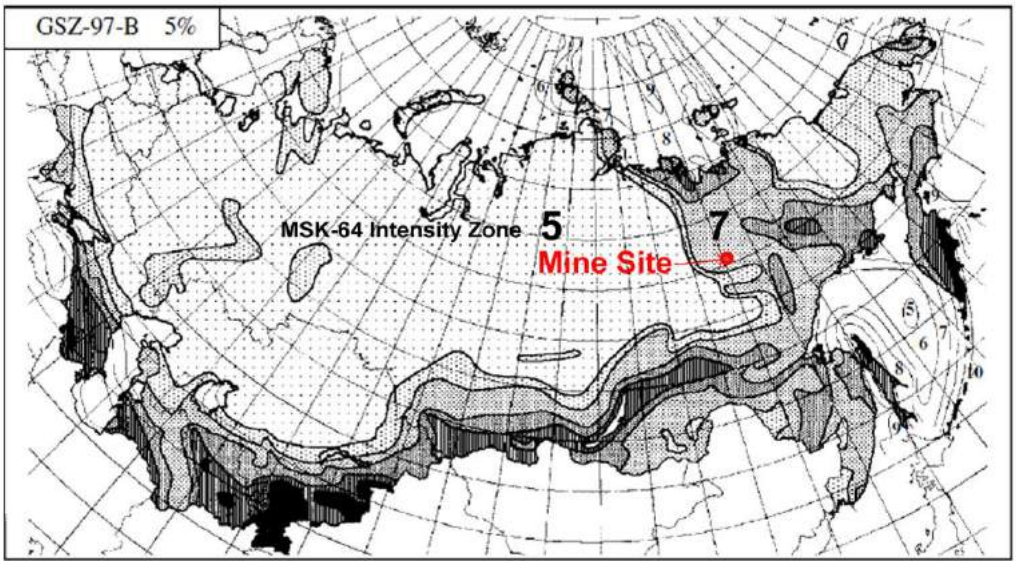
Seismic zoning is among the most complex and important components of modern seismology and seismic design. It is the process of estimating the response of soil layers under earthquake excitations, and thus the variation of earthquake characteristics on the ground surface at a project site. The study of seismicity and an adequate assessment of the seismic hazard are important for all areas where increased seismic hazard may exist and would require the implementation of anti-seismic measures.

A set of new General Seismic Zonation (GSZ) probability maps (GSZ-97-A, GSZ-97-B, and GSZ-97-C) were recently created for the Russian Federation and adjacent seismic regions, on the basis of the unified seismological and geological geophysical database. The GSZ maps of Russia are now being accepted as the basis for, and included in, the new edition of the Russian Federation National Building Code SNiP II–7–81 *Construction in Seismic Regions*.

According to the recently developed GSZ-97 maps, the probability of a possible exceedance of earthquake intensity within 50 years is: 10% (map GSZ-97-A), 5% (GSZ-97-B), and 1% (GSZ-97-C), which correspond to the mean periods of 500, 1,000 and 5,000 years, respectively, for the recurrence of such effect. The seismic effect predicted by these maps is coupled with average ground conditions in keeping with the present construction standards and rules (Russian Federation National Building Code) operating in earthquake-prone districts. The set of GSZ-97 (A, B, C) maps was endorsed by Russia's State Building Committee for the use in construction projects throughout the country. The GSZ-97-A map is recommended for the construction of common residential, public, and production buildings, while the other two maps (GSZ-97-B and GSZ-97-C) are recommended for the erection of structures that should continue in service, even during earthquakes and during work to eliminate their aftereffects (power and water supply facilities, fire stations, communication facilities, and main transportation routes such as highways). This also includes premises housing for a large number of people (hospitals, schools, kindergartens, railway stations, air terminals, theatres, roofed-in markets, stadiums) and for buildings higher than 16 stories.

The zoning on the three GSZ-97 (A, B, C) maps reflect the MSK macro-seismic intensity scale. The MSK scale has 12 intensity degrees and is somewhat similar to the Modified Mercalli Intensity (MMI) scale, used in the United States. The intensity of an earthquake is based on the extent of the damage to buildings and other observed effects on people, near the epicentre of earthquakes. Earthquakes with an intensity degree of up to 6 generally have no impact on buildings of good design and construction. However, in areas with potentially very strong earthquakes, an intensity degree of 7, serious damage may happen to old, substandard, and poorly constructed buildings. Figure 18.15 (GSZ-97B) shows that on the Project site the expected seismic intensity is MSK degree 7; therefore, buildings should be designed to resist potentially strong earthquakes.

**Figure 18.15 Peak Ground Acceleration Map of Northern Eurasia – 5% Probability of Exceedance in 50 years**




Source: Global Seismic Hazard Assessment Program

As opposed to intensity, the magnitude of the earthquake is a measure of its strength. The magnitude, M, of an earthquake is not based on the extent of the damage to buildings, but determined from the logarithm to base 10 of the amplitude, recorded by a seismograph. The magnitude is typically measured on the Richter Magnitude Scale. The largest known shockwaves on Earth had magnitudes in the 8.7 to 8.9 range.

Figure 18.15 shows the map of seismicity and seismic regionalization of Northern Asia, where zone 4.4 represents the Verkhoyansk region. As shown on the map, although a few earthquakes have been recorded somewhat north of the mine site, the area of increased seismic activity is located well to the east from the site, within the region.

As described earlier in this section, the intensity and magnitude of seismic events are observed and recorded near the epicentre of earthquakes. Based on ongoing field observations by seismic agencies around the world, it is well documented that the intensity of an earthquake may vary greatly within the impacted area of an earthquake. This is related to the fact that regional geology has a large impact on the characteristics of ground motion, generated by seismic activities. This means that a site response to the ground motion may vary in different locations within a seismic region according to the local soil conditions. Country wide seismic zonation maps may, therefore, be somewhat inadequate for detailed seismic hazard assessment of individual sites. Although they provide initial guidance for a general area within a country, that information must be further evaluated with the consideration of the actual site geology (soil and rock conditions) and proposed structural systems for buildings on a particular site.

During Tetra Tech's QP site visit, there was no indication of any earthquake induced slope movements in the area of the mine site. The steep slopes are formed from solid rock masses, and all-weathered rock movements appear to be related to gravity (rolling of dislocated cobbles and boulders off the rock slopes into the adjacent

valleys). It must be pointed out that earthquakes may have detrimental effects in areas where relatively thick saturated soil overburden covers the underlying bedrock, and the soil layers are either sensitive to liquefaction (loose saturated uniform sands) or may lose their shear strength when seismic activity may increase the pore water pressure in them (soft to very soft clays, that are always saturated). Based on field observations, there are no such soil formations at the Mangazeisky site. It should also be pointed out that soil-structure interaction effects that take place during seismic excitations govern the seismic response of foundations for buildings. Except for cases where liquefaction occurred, or sensitive clays lost their shear strength under cyclic loading, foundations failures during earthquakes are extremely rare.

Based on the summarized information in this section, it appears that the Project site is located away from potentially destructive seismic activity areas, and the potential for earthquakes greater than 6.5 on the Richter scale is negligible in the immediate vicinity of the mine site. The relevant seismic hazard map (GSZ-97-B) classifies the area as having intensity degree 7 on the MSK scale, assuming general soil conditions near a potential epicentre, and for structures that should continue in service, even during earthquakes. A review of the actual geology of the site also indicates that the site-specific response to a potential earthquake would be negligible, assuming that all structures are constructed in accordance with relevant design standards, and that all foundations are established either on solid rock or on well drained granular soil (weathered rock) subgrade and are free of any organically contaminated soil or ice pockets.

### 18.5.3 Architectural Design Basis

The architectural design basis for the site facilities are noted as follows:

- Buildings will be provided for the plant infrastructure. Crusher equipment and equipment not housed within the process plant will be exposed to the environment. Buildings that require large open spaces and overhead cranes will be of portal frame construction. Sandwich panel sheeting will be used to provide insulation, protection against wind and rain, and for security. Large roller doors will be used to provide access and ventilation.
- Where liquids are stored or handled, a sloped bund will be constructed as an integral part of the building, complete with sumps.
- Process plant bunds and sumps will be designed to eliminate cross contamination and short circuiting of process streams.

Buildings and roads will be arranged, where possible, to eliminate the need for vehicles to reverse.

Materials local to the region will be specified for use where possible.

## 18.6 Site Roads

### 18.6.1 Access from Airstrip to Camp

The airstrip is located approximately 10 km south of the Property, which includes the mine site and the new camp site (Figure 18.6). The access road to the new camp site

runs along the Sirelendge River, which has seasonally higher water levels in the valley, but remains frozen during most of the year. The condition of the route is generally poor during the summer months and will require upgrading in order to provide acceptable driving conditions from the airstrip to the mine.

The present condition of the valley floor is shown in Figure 18.16. Large quantities of granular rock fragments including boulders, cobbles, and gravel-sized particles are available along the road alignment and may be used to upgrade the existing un-graded road into a gravel-surfaced access road to the mine.

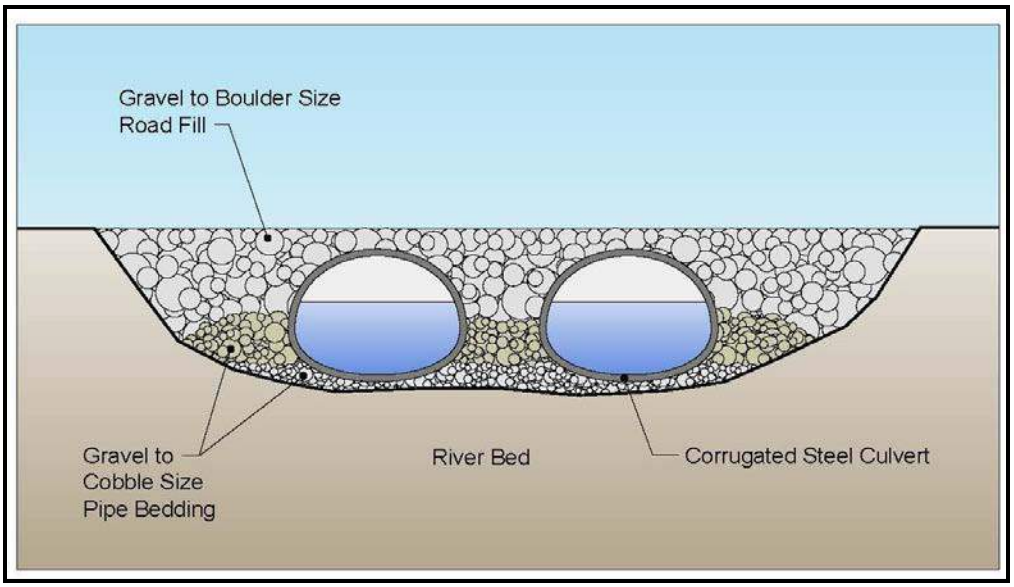
**Figure 18.16 Gravel, Cobbles, and Boulders on the Valley Floor of the Sirelendge River**

Presently, vehicles drive along the gravelly, cobble bank of the shallow Sirelendge and cross the river approximately 1.5 km downstream from the new camp site. Although the granular soils along the river banks generally provide good riding conditions for ATVs, some upgrade (re-grading) of the surface along the road alignment may become necessary. Since the river valley is generally wide, there is no shortage of clean, inert, granular material on the valley floor for such a road upgrade along the entire alignment.

For sections of road not on the riverbed and above the high-water level, the suggested cross section will be the similar to the internal mine roads specified for the road network across the mine site. The only difference will be in the width of the road, since the traffic between the airstrip and the camp site will require only one lane. The total width of this road will be 5.6 m, as opposed to 9.8 m for all other roads. Upgrading the road should be carried out during the summer months, when excavation and placement of the road fill material will be possible without encountering large quantities of ice and frozen soil. Mine personnel will complete the upgrade and annual road maintenance using equipment on site.

The river crossing will be upgraded with the installation of corrugated metal culverts in order to facilitate the free flow of water in the river during summer months, and easy driving conditions across the river for the ATVs above the culverts (Figure 18.17). The culverts will be sized based on the maximum anticipated river flow and the crossing will be designed to take into account annual fish migration (if any).

**Figure 18.17 River Crossing Upgrade with Culverts**




It is likely that during many months of the year vehicles will need to drive on ice along sections of the frozen river. To reduce the risk for those working on the ice road, as well as for the drivers, strict attention needs to be paid to testing the ice to ensure that it is capable of supporting the traffic load to which it is subjected. Once the thickness of the ice has been identified, the boundaries of the corridor where ice bearing capacity has been established should be clearly marked with any item that clearly delineates boundaries (e.g., trees, poles, cones), and drivers should ensure that transportation trucks stay within that corridor along the frozen river.

The most frequent and intensive ice-thickness testing will take place early in the cold seasons. As ice thickness increases and drivers become more confident that all thin areas have been identified, testing may be reduced. The ability of ice to support a truck depends on ice thickness, the pressure of the water below the ice as deflection develops, the way the ice initially forms, snow cover, vehicle speed, and the load types placed on the ice cover.

### 18.6.2 INTERNAL ROADS

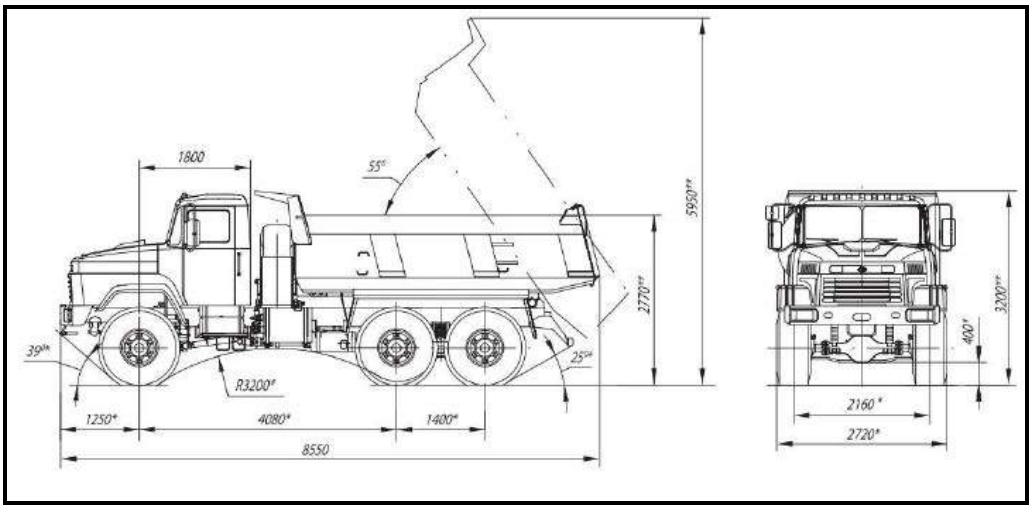
The internal roads across the mine site will connect the new camp site; the process plant; the open pit; and the ore, tailings, waste rock, and other storage facilities. The approximate alignment of the main road is shown in Figure 18.4. The current road alignment between the camp and the process plant area. The first 30% (approximately) of the existing road follows the Porfirovy Creek Valley from the new camp site, before entering a narrow side valley and climbing up toward the mine facilities, located at elevations high above the valley floor of Porfirovy Creek (Figure 18.18). The current road is presently either un-graded or running over the exposed

solid or weathered rock surface, or roughly graded with crushed, angular rock fragment fill.

**Figure 18.18 Condition of the Existing Road in the Side Valley, Where Weathered Rock and Granular Fill with Various Thicknesses Cover the Valley Floor**

The existing road upgrade, and the construction of any new road sections, will include the placement of acceptable granular fill materials over the prepared subgrade and to the specified width and thicknesses. The width of the road will depend on the specifications of the widest vehicle traveling on the road. At site, this is the KRAZ 65032 dump truck (Figure 18.19).

**Figure 18.19 KRAZ 65032 Specifications**



Based on the truck's specifications, all mine roads will have a minimum width of 9.8 m (Figure 18.20). This width includes the two shoulders and the minimum safety distance between two trucks driving next to each other in opposite directions. The specified cross section for the road is shown in Figure 18.21).

**Figure 18.20 Width of Mine Roads**

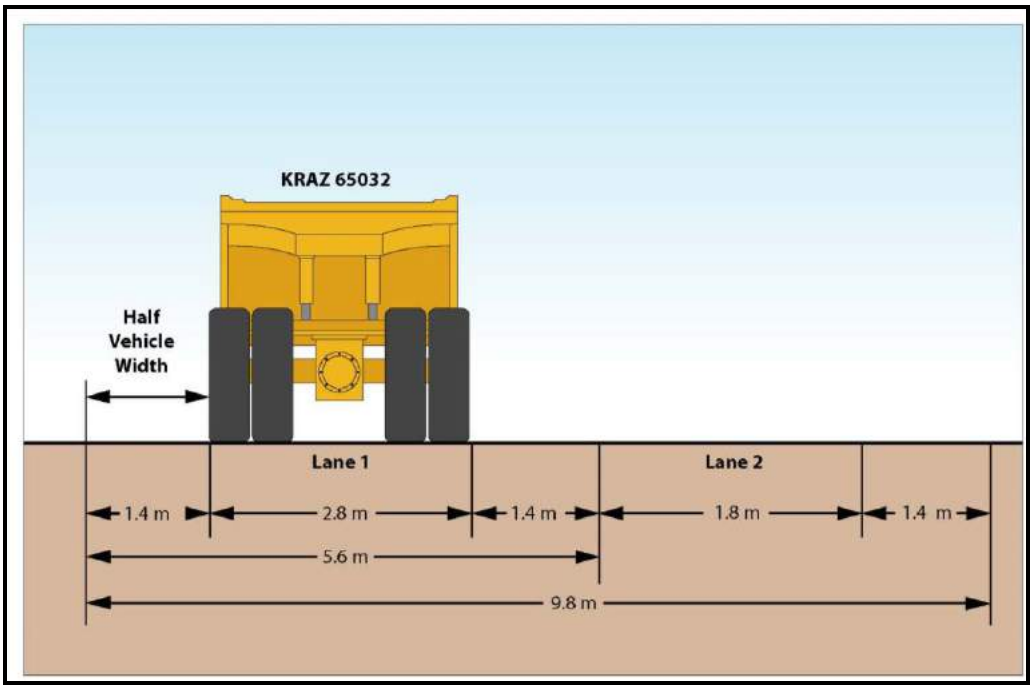
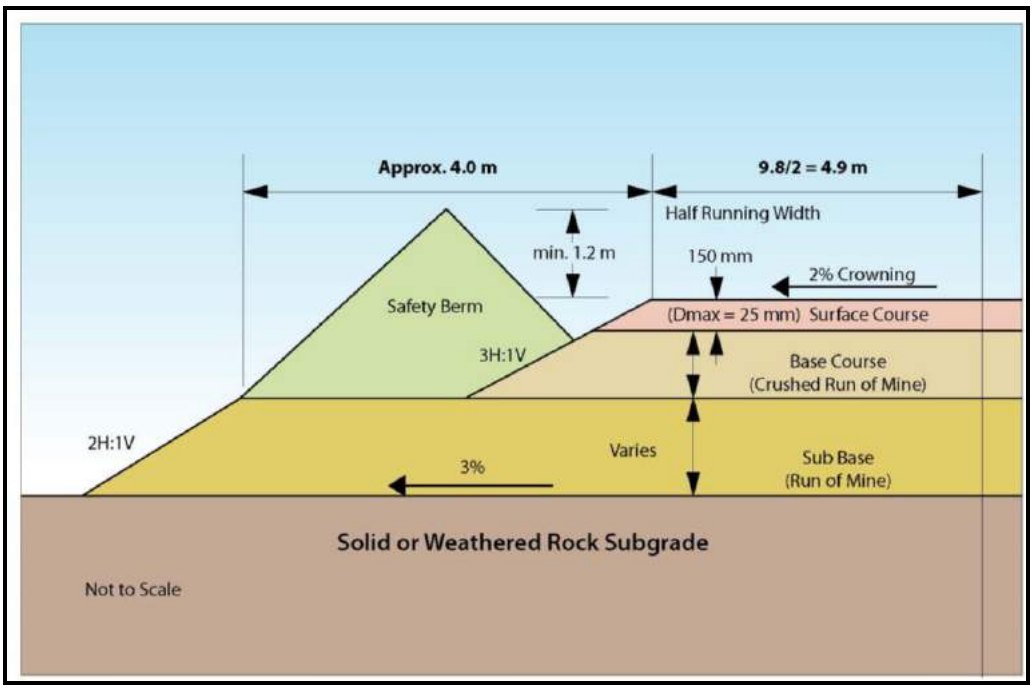



**Figure 18.21 Cross Section of Mine Roads, with Side Ditch and Safety Berm**




As shown in Figure 18.21, the individual layers within the road structure will be placed, compacted, and shaped to drain all water to the side of the road using cross-

sloping. Cross-sloping involves sloping the subgrade and road slightly to allow surface water to flow across and off the road rather than down the length of the road. Cross-sloping of the subgrade under the subbase layer will be 3%, while the road crowning will slope at least 2% toward the side ditch and safety berm. The surface water from all sources (rain or melted snow) will be conveyed from the roadway immediately in order to prevent road fill erosion, to maintain a stable road surface, and to reduce maintenance and repair costs.

Taking into account the heavy trucks that operate between the camp and mine sites, the minimum thickness of the surface aggregate (angular crushed rock) is specified as 150 mm. The crushed rock layer ($D_{max}$ = 25 mm) will be placed on a compacted base course layer (crushed ROM), which will be placed over the compacted subgrade overburden or on rock. The thickness of the base course is generally dependent on the quality (condition) of the subgrade soil. Based on observations along the existing road, the thickness of the base course at site will be 300 mm and comprise crushed ROM material, with a maximum particle size of 150 mm in diameter.

The load-carrying capacity of the road will depend on continuous, stable support, furnished by the subgrade material, which consists mainly of natural on-site soil overburden or rock; predominantly the weathered rock at the Project site. Subgrade stability requires adequate drainage and proper load distribution by the surface and base courses. Surface and base courses of sufficient thickness and quality are necessary so that the applied stress is less than the unit load capacity of the subgrade. The subgrade conditions along most of the existing road alignment are fairly good, consisting of either solid or weathered rock. It is likely that no additional subbase layer (ROM fill with a particle size of up to 200 mm) will be required between the firm subgrade and the base layer. However, within the valleys at lower elevations (Porfirovy Creek and Borisovsky Creek), it may be necessary to remove the existing soil overburden, comprising layers and pockets of frost susceptible silt and clay. Leaving silt and clay pockets within the road profile may result in softening of the fine-grained soils during thaw periods and in unwanted deterioration of the road structure through excessive differential settlement and even localized embankment failures.

**Figure 18.22 Representative Soil Conditions in the Narrow Borisovsky Valley**

Note: The cobble/boulder matrix with pockets of finer soils (silt and clay sized particles) in the valley floor

The current roads on site have been constructed by Prognoz personnel using on-site equipment. The proposed road upgrade and maintenance is not dissimilar to their current practice, and it is reasonable that future mine site road construction can be completed by the Prognoz construction team using mine site equipment, waste rock, and the on-site crusher to produce aggregate.

During periods of warm and dry weather, roadbeds will be regularly watered, as required, to keep dust levels to a minimum.

### 18.6.3 VEHICLE TYPES

Considering the difficult driving conditions—rough terrain, steeper than usual road grades at some sections of the Property, fast flowing water in the river and creek valleys during the short thawing season, ice and snow during the icy, long winter periods—only all-wheel drive, ATVs will operate at site. Based on the latest mining plan, the vehicles shown in Figure 18.23 are considered for the Project.

**Figure 18.23 All-terrain Vehicles, Planned for Operation at the Mine Site**

Ural 4320

Ural 32552

Ural ATZ Tanker

KRAZ 65032

The mobile fleet shown in Table 18.14 will be used on site as part of the process plant and infrastructure operations.

**Table 18.14 Processing and Infrastructure Mobile Fleet**

| Equipment | Unit | Quantity |
|---|---|---|
| Wheel Loader 3.5 m³ Bucket | No | 1 |
| Backhoe Loader 1.3 m³ Bucket | No | 1 |
| 40-t Truck Mounted Crane | No | 1 |
| 2-t Forklift | No | 1 |
| 25-t Mobile Crane (already purchased) | No | 1 |
| Site Personnel Carriers (Kamaz) | No | 2 |
| Lighting Plant | No | 10 |
| Mobile Crusher | No | 1 |

## 18.7 PROCESSING FACILITY

### 18.7.1 GENERAL APPROACH

The design of the processing facility takes into account the remote location of the mine site and the logistical constraints of the winter road transport window. The general approach is to ensure that machinery and equipment located outside of the building is specified to Arctic grade to allow for operation and maintenance in the extreme cold environment.

The location of the processing facility was chosen to be as close to mining operations as possible to minimise haul distances whilst taking into account the geotechnical conditions and topography of the mine site.

The process building will be winterised and heated to keep the internal temperature within 10°C and 35°C depending on the season. The majority of the process equipment, apart from the crushing circuit, will be located within the process plant building.

The main process equipment will be packaged systems supply within defined battery limits as far as possible.

Packaged equipment will be tendered for by the industry standard mining equipment manufacturers, as well as Russian manufacturers. Where possible, provided the standards set out in the equipment specifications and datasheets are met, equipment will be procured from Russian manufacturers to keep capital, lead time, and transport costs to a minimum and to reduce the tax burden. Suppliers will generally be left free to use their expertise to recommend equipment in order to meet the process parameters specified.

Equipment throughout the process plant will be standardised as far as is practical to give commonality of spares and the opportunity to hold fewer unique spares items.

Equipment will be laid out to keep pipe and cable runs as short as possible, whilst maintaining the operability and maintainability of the plant. The processing facility is run on low-voltage power, therefore, the positioning of the motor control centres (MCCs) within the building is crucial to achieve this aim.

The plant and buildings will be laid out to ensure that personnel do not have to unnecessarily venture outside and where necessary to keep distances to a minimum.

### 18.7.2 Process Plant Building

The main process plant building will be an 84 m by 24 m portal frame structure with an 84 m by 12 m lean-to structure attached to the southeast side of the main building. The building will be situated in a northeast to southwest direction to take into account the prevailing north-easterly winds. Both the main portal frame and the lean-to are clad with Russian specified and supplied sandwich panels to provide insulation and weather protection.

The main 24-m-wide structure will have an electric overhead travelling crane running the full length of the building, with a 20-t safe working load and a 5-t secondary hoist.

A 150 $m^3$, steel-constructed, mill feed bin will be attached to the main building at the southwest end of the building to provide buffer storage between the crushing and grinding operations. The bin will be attached to the building and insulated to allow heat from the building to thaw the ore and prevent it from freezing solid within the bin.

The building will house the process equipment downstream of the mill feed bin, reagent mixing, compressor and blower house, tailings handling, small containerised warehousing and workshop, control room, MCCs, and office and change facility.

The office and change facility will be a two-storey enclosed structure located in the lean-to section of the main building, between the reagent mixing and electrowinning process areas. It will be a steel structure with concrete block walls and poured concrete flooring. The concrete blocks will be produced locally on site.

Silver is precipitated from the pregnant solution in an electrowinning process to produce a high-grade silver slurry, which will be dried to produce silver powder. As a result, the area that contains this direct electrowinning equipment, and the adjacent silver room, will be secured and access controlled. The silver room will be located on the ground floor of the office structure and will contain the dewatering, drying and storage facilities, as well as an office for the foreman. The security office will control access to the silver room and will overlook the direct electrowinning area. A dedicated door will allow for secure vehicular access to the silver room for secure loading of the transportation vehicle. The silver powder will be flown to Yakutsk for onward transportation to the refinery once a week; two weeks' worth of storage will be provided to allow for bad weather.

The remainder of the office complex will house process and administration offices on the first floor and change facilities on the ground floor.

On the northwest wall of the process plant, a two-level steel structure will support two MCCs on the first floor, allowing cable access from the ground floor underneath the MCCs, and the control room and laboratory on the second floor, overlooking the grinding and leach sections.

There will be three, 40-foot shipping containers located on the ground floor of the northwest wall of the process plant containing a basic workshop in one, and day to day maintenance stores in the other two.

A roll shutter door in the northern corner of the process plant on the northeast wall will allow vehicular access to the process plant laydown area. The truck bay and laydown area will be serviced by the electric overhead travelling crane. During the colder months, the truck bay and laydown area will be used to park some of the mine fleet in an emergency mine shutdown.

Separate, dedicated vehicular access to the reagent mixing facility will be located in the south corner of the building on the southwest wall. This access will be used to bring the shipping containers used for reagent storage into the reagent mixing and storage area for unpacking as required.

The cyanide mixing and storage room will be an enclosed, separately ventilated room, separated from the reagent mixing area and other plant areas by a concrete block wall. There will be no acid reagents or consumables in the vicinity of this area. Access to the cyanide mixing room will be from outside of the process plant via a dedicated door on the southeast wall to allow the cyanide containers to be brought into the room.

There will be vehicular access to the compressor house from inside the building to allow for maintenance. There is also pedestrian access to the office complex on the southeast wall, and outside to the crusher on the southwest wall, all at ground level.

The building will be heated by a 3.7-MW diesel fuelled boiler, housed in a separate building adjacent to the northwest wall of the process plant building. The boiler will be located next to the process plant power generators to allow for waste heat from the generators to be used, via a heat recovery system, to pre-heat the water prior to entering the boiler.

### 18.7.3 ROM Pad and Crushing

The ROM pad and crushing facility will be located outside at the southwest end of the process plant. The mine haul trucks will carry ROM ore to the ROM pad, which is comprised of three graded piles. The ore will then be fed into the crusher plant by a front-end loader. During periods of dry weather, as required, ROM pads and stockpiles will be sprayed with water to supress dust emissions.

The crusher facility will comprises two skid mounted modular crusher units and a fine ore bin feed conveyor. The skid mounted units will be bolted to a reinforced concrete slab.

The first skid mounted unit will contain a vibrating grizzly, feed hopper, vibrating feeder, jaw crusher, and discharge conveyor. The jaw crusher will operate in an open circuit and the product will be discharged into the second skid mounted modular crusher unit via the discharge conveyor.

The second unit will contain a feed hopper, double deck vibrating screen, cone crusher feed conveyor, cone crusher, cone crusher discharge conveyor, and screen discharge conveyor. The cone crusher and screen will operate in closed circuit with the screen undersize product reporting to the fine ore bin via the fine ore bin feed conveyor. The crushing plant will be able to crush at a faster rate than the process plant requires. A diverter chute will be installed to divert the crushed ore when the fine ore bin is full. The crushed ore will be stockpiled to give buffer storage and allow continued operation when the crushing plant is down for maintenance.

The crushing facility will be an outside operation. A heated, elevated, containerised operator's hut overlooking the skid mounted units will be located to the east of the crusher units between the crusher and the process plant, with good visibility of the ROM and front-end loader activity.

The stand-alone fine ore bin feed conveyor will be of covered construction to minimise dust.

### 18.7.4 The Mill

The layout of the plant was designed to keep the building size as small as possible whilst allowing for effective operation and maintenance of the process equipment.

The ore feed will enter the process plant via a vibrating feeder at the base of the fine ore bin located in the western corner of the process plant, discharging onto the ball mill feed conveyor. The ore will discharge from the ball mill feed conveyor into the ball mill feed chute where it will enter the ball mill alongside the mill classifying cyclone underflow product and process water.

The ball mill is a 3 m diameter by 3.9 m, 500 kW ball mill located on a concrete foundation, which brings the mill centreline to 4.1 m above the top of the plant floor concrete slab. Access to the mill will be via steel walkways at the top of the concrete mill foundation.

The ball mill feed chute will run on rails set into the concrete foundation at the feed end to allow it to roll away from the feed head for access inside the mill. Access will be required to pass materials and equipment for liner change and mill maintenance inside the mill. Two manways, 180° apart, will be provided in the ball mill shell to allow for personnel access to the mill. Liners will be handled inside the mill by basic liner handling equipment such as the RME MILLMAST Powershift or equivalent.

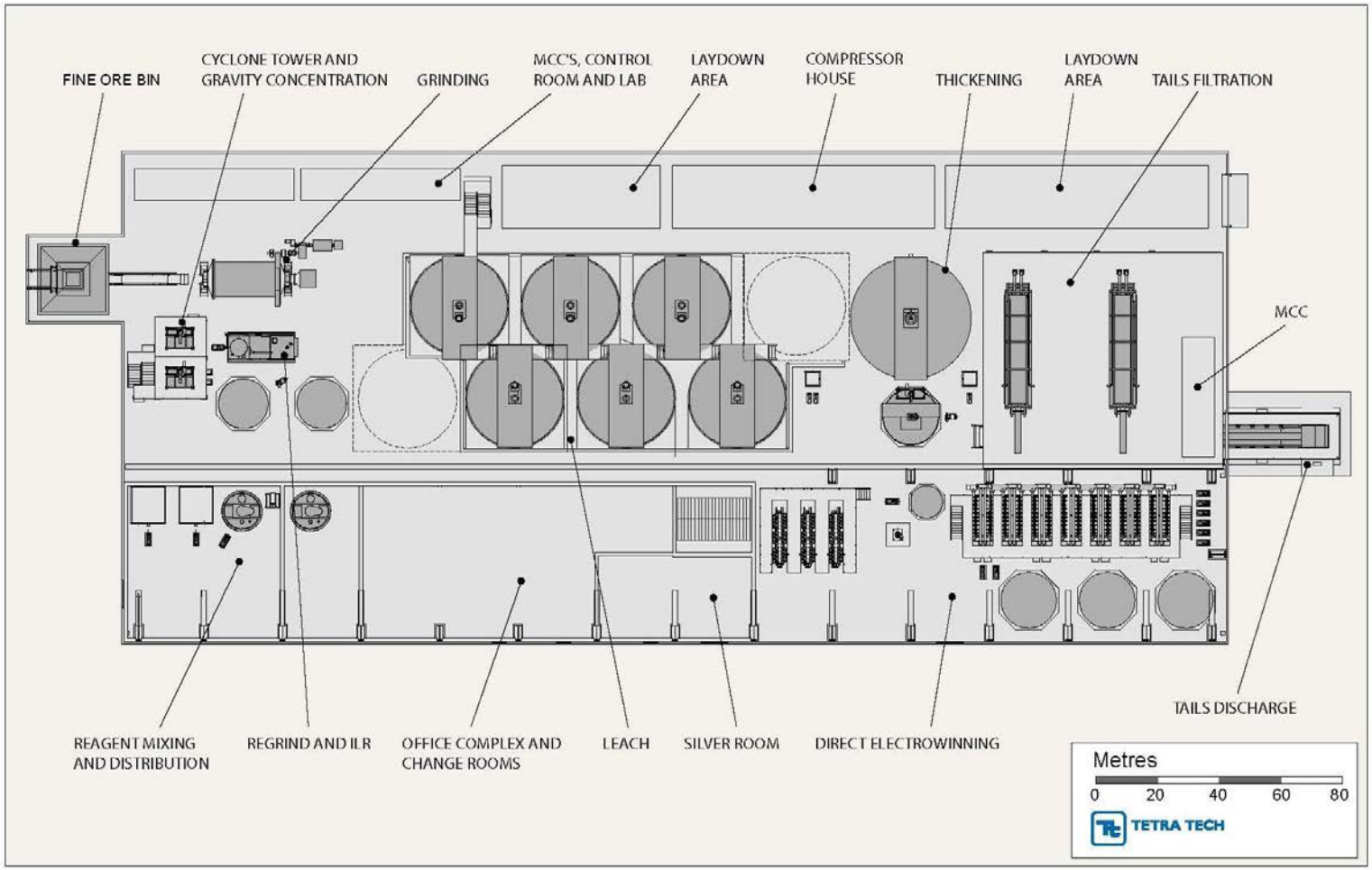
The ball mill will be charged with 90 mm diameter steel balls and must be topped up at a rate of 1 kg of steel balls per tonne of ore processed by the mill, which equates to a feed of five balls per hour. These will be loaded by hand into the feed chute from a storage container adjacent to the feed chute and will not require any ball charging equipment such as kibbles or automatic ball release mechanisms.

The cyclone tower will be located adjacent to the mill foundation, housing the classification and dewatering cyclones, gravity trash screen, and gravity concentrator. On the ground floor level the associated tanks, pump boxes, and pumps will be installed as well as the ILR. The cyclone tower will be a three level steel structure linked to the mill platform by interconnecting walkways and allowing for slurry to flow by gravity through the downstream equipment.

The leach circuit will be made up of six leach tanks. The ball mill will be sized to provide an upside in throughput of 25 to 30% given the current predicted ore characteristics. As each of the six leach tanks represents 17% of the leach capacity, space for two additional leach tanks, one at the start of the leach circuit and one at the end of the circuit, will be required to match the upside in the ball mill. Having eight tanks installed will give a retention time of 120 hours, which will allow both the future fresh sulphide ores and oxide ores to be processed in the same stream. The leach tanks will be 7.7 m in diameter by 7.8 m fabricated steel tanks designed to support the tank top walkways, agitators, gearboxes, and ventilation hoods.

The leach tanks have been arranged to allow the tanks to be of identical design. The design of the tanks includes an adjustable weir on the discharge box to allow for the gravity flow through the circuit to be regulated. Each tank will sit on a concrete ring beam foundation, but the design of the weir will allow each pair of tanks to sit at the same level, as opposed to having each tank foundation at its own individual level. This will simplify the foundations, saving construction costs and improving the operability and maintainability of the plant. Each leach tank will have a glass reinforced plastic fume hood, overhanging the tank by 100 mm and connected to an extraction fan via a common duct. The extraction fan will create a low pressure in the fume hoods to draw air in from inside the process plant and ensure that any hydrogen cyanide release is exhausted via the ducting and through the exhaust stack to the outside environment.

**Figure 18.24 Process Plant Layout**



The leach solution will report to the thickener via a clarifying cyclone. The thickener will be conventional 9 m, high-rate thickener. The thickener overflow will report to direct electrowinning and the thickener underflow will report to the filter presses for tails dewatering. The liquor from the filter press dewatering will report back to the thickener feed. The thickener will be located at the end of the leach circuit and will sit between the leach circuit, filter press, and electrowinning sections to keep the piping distances to a minimum.

The direct electrowinning package will be modular package containing a set of 140 powder cells and 84 polishing cells. The cells will be mounted on their own steel structure with the headers and manifolds provided by the vendor. The steel structure will be chemically anchored to a reinforced concrete base. The process requires three tanks to enable continuous operation. One tank will be receiving pregnant leach solution, one tank will be cycling through the powder plant and one tank will be cycling through the polishing plant. Each tank will have a capacity of 94 $m^3$ based on the assumption of changeover of tanks every eight hours and a silver concentration of 1,000 ppm in feed solution. The recommended material of construction for the tanks is fibre reinforced plastic.

The thickener underflow will be dewatered in two, 35 plate filter presses. The filter cake will be sent to the TMF and the liquor will report back to the thickener. Two smaller filter presses were selected over one larger filter press in order to level out the flow of tails downstream, as well as the opportunity for combined spares and staged maintenance. The filter presses were sized to include a cake washing cycle to ensure the highest recovery possible of the silver in solution. The filter presses will sit on a raised structural steel platform to allow for the discharge conveyors to run under the filter presses. Space has been allocated in the design for a third filter press on the platform, as an additional filter press might be required when the fresh sulphide ores are processed due to the finer grind size, or if the throughput of the plant is increased.

**Figure 18.25 Electrowinning Concept Drawing**

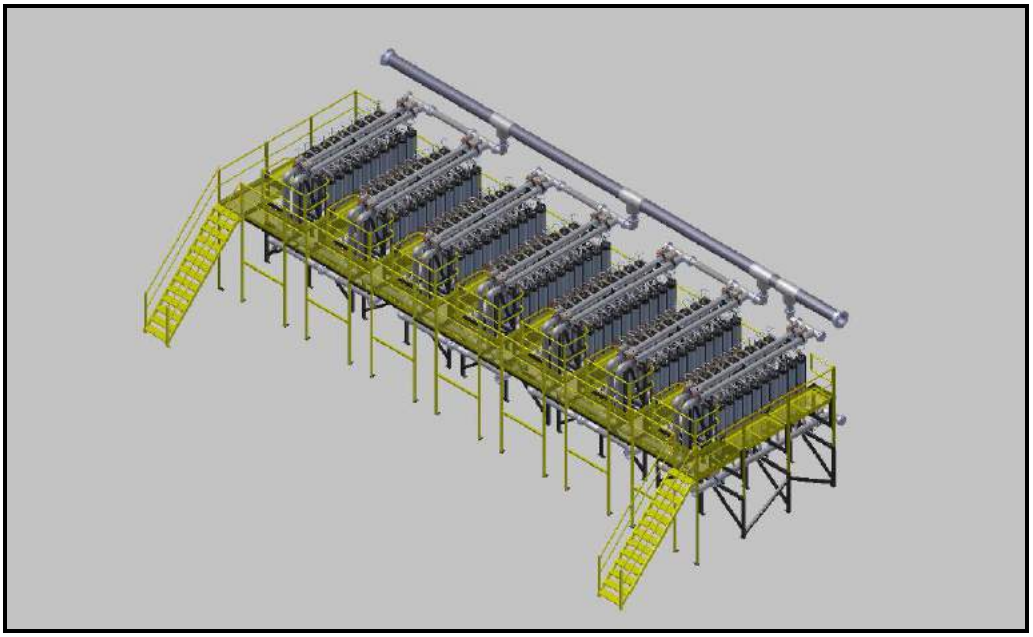


**Table 18.15 Equipment Packages**

| Package | Battery Limits | Scope |
|---|---|---|
| Ball Mill | • cyclone underflow into the ball mill feed chute<br>• trommel screen discharge | • ball mill, feed chute, lubrication units, bearings, trommel screen, motor, hydraulic jacks, gearbox, inching drive, PLC |
| Gravity Concentration and Intensive Leach Reactor | • dewatering cyclone underflow feed via the gravity trash screen<br>• discharge of pregnant solution to electrowinning<br>• discharge of tailings to the leach feed pump box | • gravity concentrator, all interconnecting piping and valve, control instrumentation, field mounted PLC<br>• intensive leach reactor, all interconnecting piping and valve, tanks, pumps, control instrumentation, field mounted PLC |
| Filter Press | • pressurised slurry feed to filter press feed valve inlet<br>• discharge of filter cake<br>• discharge of process water from filter press | • filter press frame, plates, hydraulics, internal piping and valves, instrumentation, field mounted PLC |
| Electrowinning | • pregnant solution at the suction of the electrowinning supply pump<br>• discharge of silver slurry from the silver slurry discharge pump | • powder and polishing cells, all supporting structures and access platforms, internal pumps, piping, valves and instrumentation, field mounted PLC and interface with main PLC |
| Reagents Mixing | • bulk bag reagent feed<br>• discharge flange of reagent distribution tank | • bag breaker, dust hood and ventilation, mixing tanks, distribution tanks, agitators, valves, instrumentation, field mounted PLC |

Note: PLC – programmable logic controller

All packages to be supplied top of concrete or top of steel.

The general design philosophy for piping has been to standardise pipe material and pipe sizes where possible to allow for commonality of spares, fittings, valves and pipe equipment. Pipe material has been standardised to ASTM A53 Grade B carbon steel and HDPE PE100 pipe. The largest process pipe diameter on site is 150 mm carbon steel and the most common pipe size is 100 mm diameter HDPE pipe. Piping will be designed to meet with GOST 32388-2013 and plastic piping will be designed to meet with GOST 18599-2001.

Pump boxes, tanks, chutes, bins and other platework, where possible, will be included in equipment package supply. If not available for supply as part of the equipment packages the platework will be fabricated locally on site. Generally, platework will be 6 mm thick carbon steel, with baseplates 10 mm thick, welded with 6 mm continuous fillet or full penetration butt welds. Flanges on chutes will be sealed with silicone sealant. Nozzles and flanges on pump boxes and tanks will be ANSI Class 150. Bolts will be a minimum grade of 8.8.

Conveyors will be specified as complete, turn-key items with top of concrete battery limit. The conveyor package will include all trestles, head chutes, feed chutes, pulleys, idlers, belt, support structure, pull wires, instrumentation, control, walkways and access stairs. Conveyors outside will have wind hoops specified as standard.

Access platforms, walkways and stair towers will be located throughout the process plant to ensure ease of operation and maintenance of the process equipment. Access will take into account emergency procedures and will ensure at least two exit points from access structures with no dead ends. Where stair towers are not feasible for emergency access, cat ladders will provide emergency access and egress from raised platforms.

### 18.7.5 TAILINGS HANDLING

Dewatered tails will be released from each filter press onto a cake discharge conveyor running under each filter press. The cake discharge conveyor will discharge onto a common conveyor running perpendicular to the filter presses, which will transport the cake through a portal on the northeast side of the building to discharge to a stockpile.

After dumping the ore on the ROM pad, every third ore truck will continue round the process plant building to be loaded with tails from the tails stockpile by a front-end loader. The ore truck will proceed to the TMF, 250 m to the east of the processing facility, and dump the tails in the TMF before proceeding back to the open pit.

### 18.7.6 PLANT SERVICES

A compressor house will be located in the eastern corner of the building. The compressor house will contain instrument air compressors, an air receiver, and the leach blowers.

Instrument and plant air will be distributed by a 100-mm diameter carbon steel ring main with 65 mm diameter stringers.

For oxide ore, the leach circuit requires 3.18 $m^3$/min of air at a minimum pressure of 96 kPa(g) at the sparge ring. For future sulphide ore, the leach circuit will require 6.47 $m^3$/min. The air will be introduced below the agitator blades by a sparge ring to distribute the air throughout the leach solution. Leach air will be distributed from the blower to the sparge rings by a 100-mm diameter carbon steel ring main with 75-mm diameter stringers to the sparge rings.

Process water will be pumped from the process water tank via a 100-mm ring main, supported at a high level around the plant, with 65-mm stringers dropping down to equipment and hose points. The return water will be fed back into the process water tank. Approximately 1 $m^3$/h of depleted electrolyte will be bled from the process for treatment and filtration to prevent the build-up of weak acid dissociable cyanide, base metals, and total dissolved solids in the recirculated process water.

A containerised treatment plant will be constructed on site and will be housed within the process building. The primary step in the process will be the removal of base metals in the form of metal precipitates. The barren solution discharge, approximately 15 $m^3$/h, will be conditioned with sulphuric acid and sodium

hydrosulphide in order to precipitate the copper and zinc ions as sulphide metal complexes. The cyanide ions in the solution will be converted to hydrogen cyanide during this chemical reaction which dissolved instantaneously in the process water, as hydrogen cyanide is infinitely soluble. The slurry containing hydrogen cyanide solution and metal sulphides will be pumped into a conical bottomed, static settling tank and dosed with flocculants. The metal sulphide precipitates in the settling tank underflow will be pumped to the filter press feed tank within the process plant tailings disposal area and subsequently discharged to TMF.

The settling tank overflow will be conditioned in another tank with sodium hydroxide in order to regenerate the cyanide. It is anticipated that 90% of the cyanide solution, approximately 13.5 $m^3/h$, will be recirculated back to the process plant as plant water, reducing water demand and cyanide usage.

A bleed stream of 10% of the process solution, approximately 1.5 $m^3/h$, will be pumped through a sand filter followed by a series of carbon adsorption columns and cationic and anionic ion exchange (IX) columns in order to remove any remaining contaminants including residual cyanide. The clean water from the bleed stream will be recirculated back to process water tank, used for reagent make-up or in the gravity circuit.

The treatment plant will run year round. During the summer, on average, an additional 3.5 $m^3/h$ of TMF runoff will be processed through the treatment plant. The additional water will be used for reagent make up. Should the tailings runoff marginally exceed the capacity of the water treatment plant, raw water supply to the process plant will reduced and process water used in its place as a temporary solution. Should the tailings runoff increase further, for example, during a 1-in-100-year extreme precipitation event, the runoff will be dosed with calcium hypochlorite in situ, in the TMF runoff collection pond, and mixed using floating agitators and aerators to neutralise the cyanide.

The raw water supply pipe will discharge into an 8-m diameter by 8-m insulated raw water tank, heated with a 15-kW immersion heater. The raw water tank will supply the plant with fresh water, make-up water, top up the fire water tank, and supply the containerised potable water treatment plant with fresh water. The raw water pumping station is detailed in Section 18.16.2.

The potable water will be treated raw water. The potable water treatment plant will be a containerised unit, taking feed from the raw water tank, processing the water and feeding the potable water tank. From the potable water tank, potable water will be pumped round a ring main to the plant facilities, wash rooms and process equipment, namely the ACACIA reactor and gravity concentrator, requiring clean water.

The fire water tank will be located in the water treatment complex alongside the raw water tank and potable water tanks. The fire water tank will be fed from the raw water tank with fresh water. The fire water tank is the feed for the fire water system, which consists of a fire water ring main, fire water pump, jockey pump and backup pump. The fire water ring main will run through the garage warehouse building and process plant building with stringers to provide fire hose points at the required locations.

### 18.7.7 Process Instrumentation and Controls

An uninterruptible power supply (UPS) will supply power to the control and instrumentation system. The control system is designed for semi-automation of the process plant. The control system architecture design consists of a central PLC and a supervisory control and data acquisition (SCADA) operator interface within the process plant, with distributed input/output (I/O) hardware at the various infrastructure sites. The process control includes the following operational modes:

- automatic
- local
- manual.

Every motor is designed to have a field start/stop push-button station to enable local control. Hard wired emergency stops must be provided in locations as chosen by risk assessment.

The instrument design takes into account maximum and minimum operating conditions, desired accuracy, response required, and commonality of spare parts.

It is expected that the control system design will require the involvement of a systems integration specialist.

The infrastructure process control will be designed for a semi-automated control with a minimum amount of operator interaction required. The process plant PLC/SCADA system will control the entire project site, with remote I/O connected back to the central PLC via fibre optic cable.

### 18.7.8 Processing Facility Closure Plan

Upon closure of the mine, a number of operations will be required to make the plant safe. Structures, buildings, and all equipment will remain in place. All tanks, pipes, and vessels containing potentially hazardous slurries and solutions, including, but not limited to, the leach tanks, electrowinning, reagent mixing and distribution, and pump boxes will be cleaned and flushed thereby neutralising the substances. Oils and coolants will be drained from machinery into sealed barrels. The coolants will be stored in the waste storage facility and oils will be burnt in the process plant boiler.

## 18.8 Site Facilities

The following section provides an overview of site buildings and supporting facilities. An overall site plan, including arrangement of buildings on the site and layouts for each of the main buildings is presented in Figure 18.5.

### 18.8.1 Garage/Warehouse

Located to the east of, and running perpendicular to the main process plant building is the garage workshop building. The building itself will use an existing 40 m by 20 m by 8.4 m high warehouse building available on site, with a new 20 m by 20 m by 8.4 m high garage extension to make a new 60 m by 20 m building which will be clad

with Russian specified and supplied sandwich panels to provide insulation and weather protection.

The new 20-m garage extension will house three vehicle bays, each with roller shutter door. The bays will be designated a vehicle wash down bay, a welding bay, and a repair bay with an under vehicle access pit. The welding and repair bays will be serviced by a 5-t gantry crane.

The 40-m workshop section of the building will contain a mezzanine floor for storage of lightweight spares. The ground floor of the workshop section will contain general workshop equipment such as hydraulic jacks, drills, sanding machines, pullers, and compressors. In addition to the general equipment there will be specialist sections for tire change and storage, axle maintenance, engine and gearbox maintenance, battery charging and brake maintenance, as well as a foreman's office and washroom facilities.

During periods of extreme weather when mining operations are shut down, the unused vehicle maintenance bays will be used to park some of the mining fleet to prevent them from getting too cold for restart.

### 18.8.2 Fire Station

The fire station will be located within the process plant complex. The building will be of steel construction and clad with Russian specified and supplied sandwich panels to provide insulation and weather protection.

The building will contain covered parking for the fire fighting vehicles with water tank refill equipment and roller shutter door, shift office, changing room, training room, equipment stores and a mess room.

### 18.8.3 Operation and Construction Camp Accommodation

The operational camp facilities will be located in the valley bottom next to the Sirelendge River. The operational camp will be an expansion of the original exploration camp. The operational camp will be constructed in two phases. The first phase of camp accommodation will comprise a two storey, 12 m by 49 m, 80 bed accommodation block, mess facilities and food storage for 80 workers, a 128 $m^2$ bath and laundry complex, and warehousing for housekeeping maintenance spares, food, and consumable storage. The second phase of camp accommodation will comprise a second two storey, 12 m by 49 m, accommodation block configured with 40 beds with the remainder of the building housing rest and recuperation facilities. Water will be supplied via a containerised potable water plant, from the raw water pump station. The camp will have its own 645-kW generator and fuel storage, used to provide power to both the camp and the raw water pump station.

The construction camp will be a 50-person, winter proof, containerised temporary camp with mess and laundry facilities, located next to the process plant.

#### *Medical Centre*

There will be a medical centre located at the operational camp with a doctor on site. Injured and sick workers will be transported back to the camp in site vehicles for treatment.

### 18.8.4 Airstrip

The current airstrip allows access to site via helicopter or an Antonov AN2 fixed wing aircraft. The runway is approximately 800 m long and can be extended to 1,200 m. As neither of the aircraft mentioned can fly above 3,500 m in altitude, and the site airstrip does not have telemetry, lost flying days are estimated to be between 50 and 75% due to poor weather conditions. To mitigate for the risk of lost flying days, the shift rosters will be staggered and the secure silver store room will have the capacity to hold several week's production of silver powder.

### 18.8.5 Helicopter Pad

A helicopter landing zone has been designated at the camp area and clinic. Helicopters will be used for medical emergency evacuation.

### 18.8.6 Site Facilities Closure Plan

Buildings and equipment, including generators, will remain on site. Any oils, hydraulic fluid, coolant, and other hazardous substances will be drained from equipment and stored in sealed barrels. Oils will be used as fuel in the diesel boilers. All other fluids will be stored in the waste storage facility in sealed barrels. Any equipment with stored energy will be dismantled or made safe.

For a period of at least one year, a small team of personnel, accommodated in the local village of Sebyan-Kyel, will monitor the site on a weekly basis and take samples to ensure that the storage facilities and mine closure measures are effective.

## 18.9 Remote Site Facilities

### 18.9.1 Offices

The Project will be remotely supported by management, administration and engineering teams based in an office located in Yakutsk. These functions do not need to be based at site incurring accommodation, travel, and rotational costs and will only fly out to site as required.

### 18.9.2 Refinery

Dried silver powder in sealed and tagged 30 l HDPE drums, flown from site, will be transported directly to a third party refinery from where doré metal will be sold directly. Once the silver metal powder arrives at the airstrip near Yakutsk, no handling (other than off-loading from the plane) or storage of silver metal by Prognoz will be required.

## 18.10 TAILINGS MANAGEMENT FACILITY

Silver Bear commissioned SRK to undertake the feasibility engineering design for the TMF for the Project.

SRK undertook a TMF site selection study, in which a series of four alternative locations were assessed for development. A waste rock and tailings co-disposal option was also considered as part of this assessment.

The preferred location for TMF development is indicated in the site layout in Figure 18.4.

The TMF will be constructed 0.2 km northeast of the plant site and will cover an area of 7.69 ha. Approximately 0.8 Mt of tailings material will require storage over the LOM.

The full TMF study completed by SRK is located in Appendix J.

### 18.10.1 TAILINGS PROPERTIES

Tailings will be dewatered at the plant to produce a filter cake, with a minimum solids content of 85% w/w. This dewatering methodology was selected by Tetra Tech and SRK to minimise potential impacts on the environment and simplify materials handling.

As the tailings material was identified as having potential for metal leaching, the TMF has been designed as a fully-lined facility. There will be zero discharge of process affected fluids. To achieve this goal, runoff and any seepage water will be collected in the clarification pond, located at the eastern end of the TMF. The water will then be processed in the treatment plant and used as make-up water in the process circuit.

Limited materials testing has been carried out on representative tailings samples, which indicate that the material consists of predominantly fine grained material.

### 18.10.2 TMF DESIGN

The TMF consists of two components:

- filtered tailings (or dry cake) storage area
- clarification pond

The waste storage area of the TMF will consist of a high-density polyethylene lined pad surrounded by a rock fill perimeter berm. The perimeter berm will vary in height (maximum height above natural ground of 6 m) and its function will be to separate the clean surface water (runoff water from the surrounding topography) from the process affected water (runoff water from the dry cake storage area).

At the eastern toe of the TMF waste stack, a clarification pond will be excavated below the original ground to the depth of approximately 3 m and the associated perimeter containment dam will be limited to a height of approximately 9 m above

original ground level. The clarification pond will be fully lined with the seepage collection sump at the downstream end of the contained area. Because of the limited height, the perimeter containment dam will be built of rock fill lined with HDPE. Neither internal filters nor a clay core will be constructed within the containment dam section. The rock fill used in its construction should be of sandstone origin (to limit the percentage content of carbonate rock).

### 18.10.3 TMF Operations Strategy

Tailings will be delivered to the storage site in form of dry cake at 12 to 15 % moisture content using a single 20-t haul truck sourced from the mining fleet. Tailings will be loaded from the stockpile outside the plant onto the truck using a dedicated JCB 4CX ECO backhoe loader (1.3 $m^3$ capacity). Upon deposition at the TMF site, tailings will be spread in nominally compacted by a D7 dozer (also sourced from the mining fleet). Dozer traffic over previously deposited tailings will aid of a process of compaction and negate the requirement for specific compaction equipment.

The initial and first lift on the top of the HDPE liner in the stacking area should be 1 m thick to protect the liner, following on from this lifts of maximum 0.3 m thickness to aid improved compaction. SRK has taken into account the effect of freezing of tailings during volumetric calculations.

SRK used data obtained from a geotechnical investigation at the site (performed by others) to characterise the foundations beneath the TMF. In addition, limited test work carried out on representative tailings samples has been completed (by others), which has been used by SRK to characterise the shear strength properties of the filtered tailings for design. Based upon this data, SRK has completed slope stability analysis to confirm that the TMF waste slope factor of safety is acceptable under appropriate static and seismic loading conditions.

The TMF construction risks include inability to install the synthetic liner in low temperatures (in winter). If the construction works are not properly scheduled or delayed then the completion of the TMF may be postponed until the spring or summer months.

### 18.10.4 Closure and Rehabilitation Plan

A closure and progressive rehabilitation plan has been completed for the TMF, which incorporates the following components:

- re-grading of the TMF to ensure all external slopes are less than or equal to 1V:3H
- placement of 1.5-mm HDPE geomembrane across the stored tailings material
- placement of a geotextile protection layer above the HDPE
- installation of a 1.0-m waste rock layer for erosion protection
- installation of a 0.2-m topsoil final cover.

The final tailings surface has been designed to encourage shedding of meteoric runoff to the perimeter of the structure.

Monitoring provisions have been included for both the operational and closure period, which include standpipe piezometers for water quality monitoring.

## 18.11 WASTE ROCK DUMP, ORE STOCKPILE AND OVERBURDEN STORAGE AREA

The three types of soil and rock streams that will require temporary storage or permanent disposal at selected locations across the mine site are: topsoil (generally weathered rock fragments), ore, and waste rock. The selected locations for the temporary storage or permanent disposal of these materials are shown in Figure 18.4.

The selection of appropriate locations for the storage of these materials is one of the most important aspects of the mine layout design. The selection process is largely influenced by:

- environmental constraints/impacts
- material characteristics
- design volume of the ore/rock streams
- storage capacity
- site availability
- capital, operating, and closure costs
- geotechnical, geological, hydrological and hydrogeological conditions
- ease of the day-to-day operation of mining and processing.

Other site selection considerations include:

- topographic boundaries
- location of ore bodies (open pit/underground shafts)
- surface water management and diversion
- available area and expansion potential
- proximity to existing infrastructure elements
- distance and elevation from the open pit and from the processing plant
- seepage control
- climate
- suitability of seepage and runoff collection pond(s)
- seismic conditions
- sub-grade soil and rock conditions.

### 18.11.1 Ore Stockpile

Ore from the open pit and underground mine will be transported to the process plant by dump trucks. Prior to crushing, the ore will be stockpiled in an area located immediately southwest of the plant, as shown on Figure 18.4. The ore stockpile site is generally flat and has firm ground, and comprises weathered rock fragments over shallow, solid bedrock. No ore stockpile instability is anticipated, as long as the side slopes of the individual ore piles are 1.5H:1V, or shallower.

According to project details, ore will be stockpiled in a heaped formation in four individual areas. Three smaller heaps will be formed to store run of mine ore of different grades. The estimated volume of each small pile will be 460 $m^3$ and each will individually cover an area of approximately 300 $m^2$. The use of smaller, individual ROM stockpiles is critical to the mining operation in order to supply product of the correct specification, and smaller ROM stockpiles are usually built depending on the product grades, derived from the open pit faces. Next to the three ROM piles, immediately to the northwest, is the largest of the four stockpiles where the ore will be placed next to the primary crusher in a heaped pile of up to 12,300 $m^3$ in volume. The approximate area of this primary location will be 5,600 $m^2$.

The ore stockpiles will be located next to the process plant, on the top of the plateau; therefore, no runoff water is expected to come into contact with the dumps, and only a limited amount of precipitation will enter the voids of the ore, which will eventually end up in the process plant. As a mitigating measure, contact water around the dumps will be collected in ditches and re-used in the process plant via the TMF. Such ditches may be formed around the individual ore stockpile heaps. Based on the available weather data, the anticipated amount of such water will practically be negligible. Any water collected will be transported to the TMF via mobile water bowser.

### 18.11.2 Overburden Stockpile

Selected areas on site, impacted by mine development, will require clearing of any soil overburden. Such overburden generally comprises layers or mixes of clay, silt, sand, gravel, cobble, and boulder sized rock fragments and soil particles. At the Project site, the overburden generally comprises gravel and cobble sized rock fragments, with limited amount of fine (silt and clay) particles. It is likely that the finer soil fractions have washed down from the top of the mountain and mountain slopes by occasional runoff water during short summer storms. Prior to pouring foundation concrete for the individual buildings, and prior to the start of the open pit, all soil overburden will be removed from those areas and stockpiled for potential re-use during mine closure. Since the largest amount of such soil mass is expected to come from the open pit area, the temporary storage place for the topsoil will be next to the open pit, as shown on Figure 18.4.

The available volume for topsoil storage is 205,790 $m^3$, while the area of the topsoil heap's footprint is approximately 35,640 $m^2$. The ground surface at the topsoil storage site slopes somewhat toward south-southeast. A runoff collection trench will be formed around the storage heap in order to facilitate the collection of any storm water and convey it into the seepage/runoff collection and settling pond, which will be constructed at the front of the proposed WRD. The primary purpose of the settling pond will be to capture all solid particles conveyed into the pond by precipitation and

to prevent those solid particles from entering the Borisovsky Valley. It must be pointed out that due to the limited relevant surface area, the anticipated volume of run-off water is practically negligible.

### 18.11.3 WASTE ROCK DUMP

*LOCATION*

The waste rock mass generated during the excavation of the open pit and advancement of the underground mine shafts will be placed into a short side valley, located immediately east of the open pit (Figure 18.4). Trees currently cover parts of the side slopes in the valley selected for the WRD; however, these will be removed. Once the dump is closed, new trees will be planted on the top and on the new slopes of the WRD.

At the front of the proposed WRD, next to the junction of the side and the main Borisovsky valleys, a seepage and runoff water collection/settling pond is proposed for construction. The crest elevation of the perimeter berm around the pond is proposed at the 1,039 masl elevation, while the maximum water level in the pond is anticipated at the 1,035.5 masl elevation.

The soil conditions in the Borisovsky Valley can be characterized by relatively shallow overburden over solid rock. The soil overburden generally comprises a matrix of gravel, cobble and boulder sized weathered rock fragments, with some silt and clay filling the voids of the large, angular cobbles and boulders (Figure 18.26). In order to prevent any potential instability and unwanted settlement of the proposed perimeter berms around the settling pond, it is recommended to remove the existing soil overburden from the footprint of the berms and to construct the berms from well-graded, clean rock fill, comprising gravel to cobble sized waste rock fragments. The side slopes of the berms using such material are generally stable, with slopes of 1.5H:1V; however, considering that water flow during storms is potentially faster, the recommended slope inclination should be 3H:1V or shallower. Since fine-grained soil fraction (fine sand, silts, and clay) is available only in limited quantities within the voids of the generally coarse grained matrix, there is no continuous natural filter layer in the area to provide the required turbidity barrier within the settling pond. Therefore, the berms' upstream face and the base of the pond may potentially require the placement of a Type 3 silt barrier in order to prevent any solid particles leaving the pond and entering the Borisovsky Valley. As it was pointed out earlier, the soil overburden across the plateau and side slopes of the mountain comprises clean gravel to boulder sized rock fragments. The anticipated amount of fine soil particles in the settling pond will, therefore, be negligible.

**Figure 18.26 General Soil Conditions at the Floor of the Borisovsky Valley (Cobbles and Boulders with Some Silt and Clay Filling in the Voids)**

### *Geochemistry of Waste Rock*

Geochemistry tests were completed by the Russian Laboratory of Geoelectrochemistry No. 571, under the supervision of Institute of Oil and Gas Geology and Geophysics on representative waste rock and tailings samples to evaluate the neutralizing potential of these materials using Sobek's method. As part of the testing program, experiments of intense oxidation on 26 selected samples (24 waste rock samples and 2 tailings samples) were completed, together with the evaluation of acid-generating potential (AP) and neutralizing potential (NP) of overburden rocks and tailings. The following paragraphs summarize the test results, provided by the Geoelectrochemistry Laboratory.

Reportedly, the tests resulted in preliminary findings regarding the neutralizing capacity and composition of waste rock, and possible ingredients of drainage water, which may be formed as a result of the interaction of seasonal precipitation with the waste rock within the proposed dump.

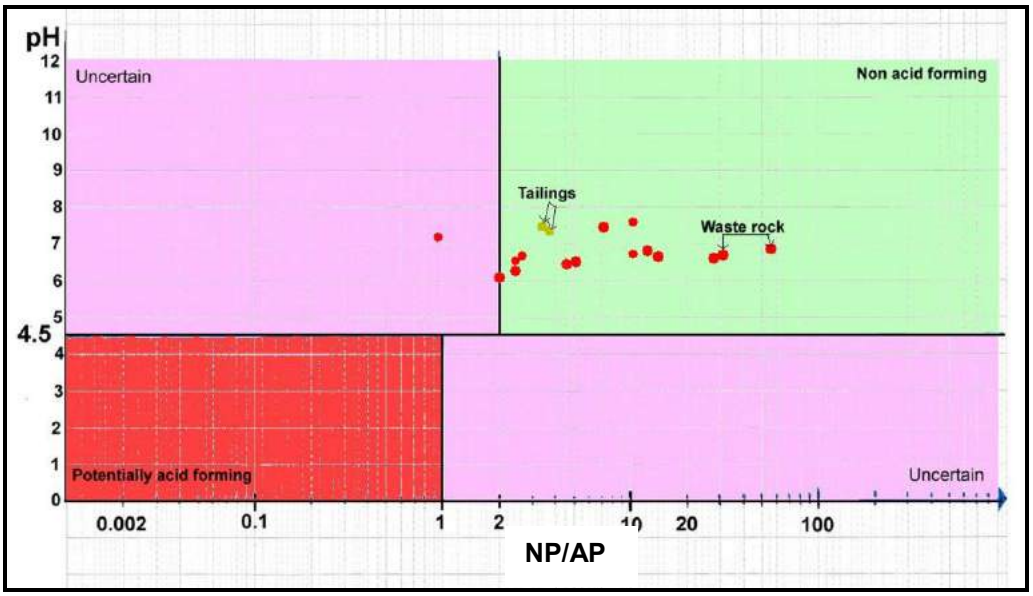
The amount of sulphur in the tested rock samples was relatively low and exceeded 1% in only three rock samples and in both of the two tailings samples. In nine samples the sulphur content was greater than 0.5%. In the remaining samples it did not exceed 0.5%, while in seven samples sulphur content was below the detection limit of 0.01%. The distribution between various forms of sulphur (sulphate and sulphide) in sulphide rocks was sporadic; however, sulphide sulphur prevailed in the tailings samples.

The carbonate content in the waste rock samples varied widely from less than 0.01% to 10% carbon dioxide. In 16 samples the carbonate content exceeded 2%, but at the same time, in 16 other samples, it did not exceed 1%. In general, on the basis of definition of sulphur forms, the preliminary conclusion is that the overburden rocks have relatively high potential for in-dump neutralizing of any acid that may potentially be formed during oxidative dissolution of any sulphides that may be present in some

waste rock streams. The analysed overburden rocks and tailings samples of the Vertikalny deposit that will be placed into the WRD and TMF, are characterized by a high-neutralizing potential, as shown in Figure 18.27. The chart in Figure 18.27 presents the relationship between pH, AP and NP in representative waste rock and tailings samples.

More than 50% of the samples (23 rock samples and both tailings samples) indicated that they are not acid producing, with a high percentage of calcite content in the tested samples. In fact, in three of the samples the calcium carbonate content exceeded 100 kg per 1 ton of rock. There were a small number of test results that indicated uncertainty in connection with neutralizing potential; however, none of the tests indicated specific potential for acid rock drainage (ARD) in the waste rock.

**Figure 18.27 Relationship between pH, AP and NP in Representative Waste Rock and Tailings Samples (based on tests results provided by the Geoelectrochemistry Lab)**

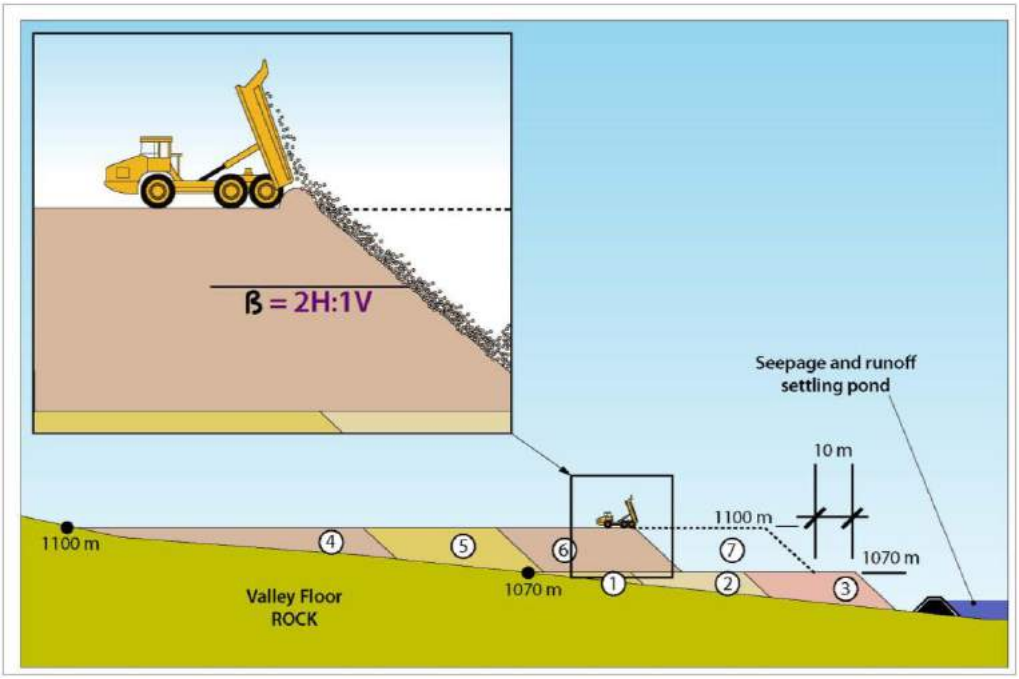



### *Placement of Waste Rock and Formation of the Waste Rock Dump*

The proposed WRD will store up to 2,765,000 m³ of blast rock material, removed prior to the extraction of ore from the open pit and underground mine shafts. Once the mining operation and waste rock disposal operation is complete, the WRD will attain a maximum height of 135 m, with a footprint of approximately 114,260 m² (11.4 ha). The toe line of the WRD will be located at the 1,040 masl elevation, close to the mouth of the side valley, next to the Borisovsky Valley.

The waste rock will be placed into the side valley in stages. The suggested sequence of the stages is shown in Figure 18.28. The placement of the waste rock shall start at the 1070 m elevation (Zone 1) and continue toward the runoff collection pond. The northern and southern sides of the dump will be backed by the existing stable slopes of the adjacent hills, while the front of the WRD (east side) will be formed with stable, benched slopes.

**Figure 18.28 Staged Deposition of Waste Rock, Starting at the 1,070 m Elevation Level**



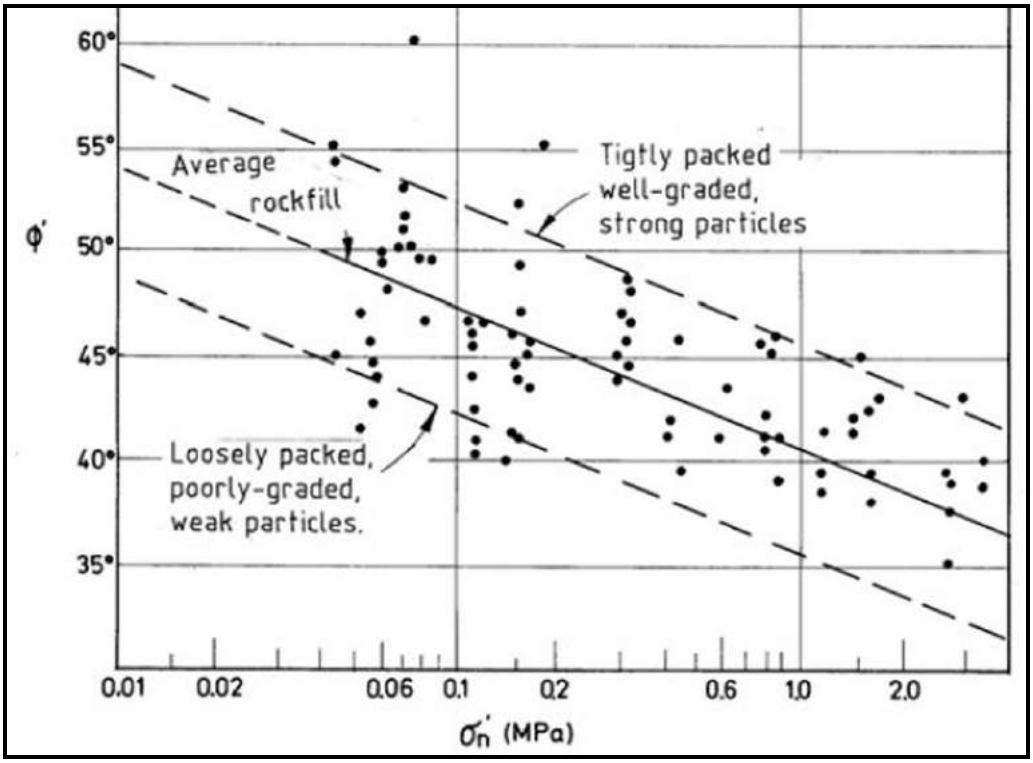

The inclination of the final face of the WRD (zones 3, 7, etc.) will be 2H:1V. That slope will remain stable, even during any potential earthquake that (in the unlikely event) may be encountered in the general area of the mine site. As noted, the potential for any seismic activity in the Project area is negligible; however, an appropriate horizontal seismic co-efficient should be considered when selecting a safe slope inclination for any soil or rock slopes.

The WRD will generally comprise gravel, cobble, and boulder sized blast rock fragments. The internal friction angle of such waste rock material may vary between 35° and 55°, as shown on Figure 18.29. Considering the fill may possibly be end dumped without additional compaction, the estimated friction angle used within the waste mass may conservatively be 42°. Therefore, the factor of safety (FOS) against potential sliding within a 2H:1V slope will be 1.77 at static conditions, well above the minimum value of 1.5.

The maximum height of each lift of the waste rock must be limited to 30 m. At the face of each lift of the WRD, a bench must be formed by stepping back 10 m, as shown on Figure 18.29.

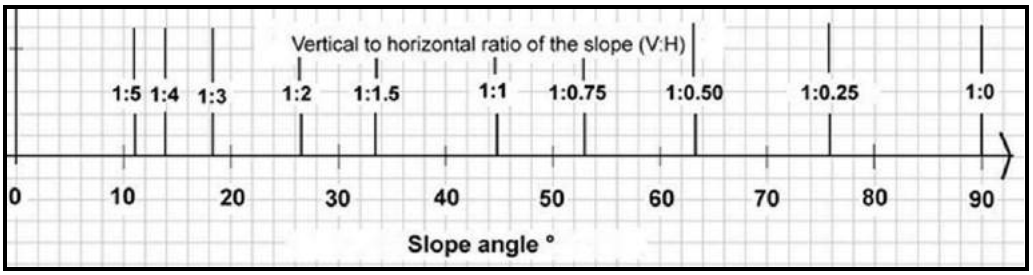
Representative slope inclinations are shown on Figure 18.30.

**Figure 18.29 Variation in Internal Friction Angle within a Rockfill Mass**




Source: Leps (1970)

**Figure 18.30 Representative Slope Inclinations and Slope Ratios (V:H)**




As pointed out above, it is anticipated that the waste rock pile will be formed by end dumping the rock fill using rigid frame rear-dump trucks. With such an operation, the larger boulders and cobbles generally roll down on the slope and build up the bottom part of the rock pile. The smaller sizes generally remain within the upper zone. Having smaller particles "blinding" the voids within the larger rock fill cobbles and boulders will help to minimize potential acid generation and metal leaching within the waste rock mass. When the large voids within the rock fill are filled with smaller particles, the potential air movement and seepage of precipitation within the rock fill is reduced, minimizing any metal leaching within the waste rock mass.

Reductions in the volume and rate of flow of drainage, especially through potentially acid generating (PAG) materials (if encountered in the pit and placed into the WRD), will maximize NP effectiveness and reduce metal loadings in the immediate vicinity of the WRD. The physical properties and configuration of PAG and non-potentially acid generating (NPAG) materials within the waste rock can also be used to minimize the leaching of PAG strata. As described previously, more than 50% of the tested

samples indicated that they are non-acid generating. One of the best available techniques to minimize any potential acid generation and metal leaching within the WRD is to place all waste rocks, presently identified as having uncertain NP, within the core of the dump (zones of 1, 2, 4, 5, and 6 in Figure 18.28). All waste rock streams having high degree of NP shall be placed within the stages that will provide the final face of the dump (zones 3 and 7 in Figure 18.28). Diverting any potential runoff water (anticipated to be negligible for all practical purposes) away from the WRD will also limit any potential leaching by incident precipitation. The alignment of the diversion ditch around the WRD is shown on Figure 18.4.

### 18.11.4 Waste Rock Dump, Ore Stockpile and Overburden Stockpile Closure Plan

The ore stockpile will be depleted during the ramp down of operations with any remaining ore run through the process plant.

During normal operation there will be spare fleet hours for the dozers because during winter mobile equipment will be kept running to stop it from freezing. The dozers will be used for progressive closure of the waste dumps during the ramp down of mining operations. The waste rock will remain in place and vegetation will be planted on the top and slopes of the waste rock dump.

The material contained in the overburden storage area will be used in the remediation of the site on mine closure in areas such as the TMF.

## 18.12 Site Water Management

A water balance model (WBM) was constructed for the Project using GoldSim, a software package designed to perform Monte Carlo simulations (GoldSim Technology Group, 2010). The WBM predicts the amount of water required to meet the needs of ore processing (milling) operations, underground mining (drilling) operations, and on-site Project staff based on the best available information.

WBM inputs are divided into five types: climate inputs, surface water inputs, human (Project staff) inputs, ore processing and milling-related inputs, and subsurface mining inputs. Each of these inputs is described in the following sections.

### 18.12.1 Climate

The climate inputs for the WBM consist of specified distributions for the average monthly temperatures at the site. In the absence of any site-specified data, the WBM uses the average long-term monthly temperatures reported by SRK for the Syuryen-Kyuyel meteorological station, which is the closest station to the mine site (Appendix K). Table 2-2 of the SRK report (Appendix K) provides the minimum ($T_{min}$), average ($T_{avg}$) and maximum ($T_{max}$) monthly temperatures in degrees Celsius. GoldSim requires the minimum, mode (most likely; $T_{mode}$) and maximum as inputs to define the triangular distributions for temperature. The mode of each monthly temperature distribution was calculated using the following formula:

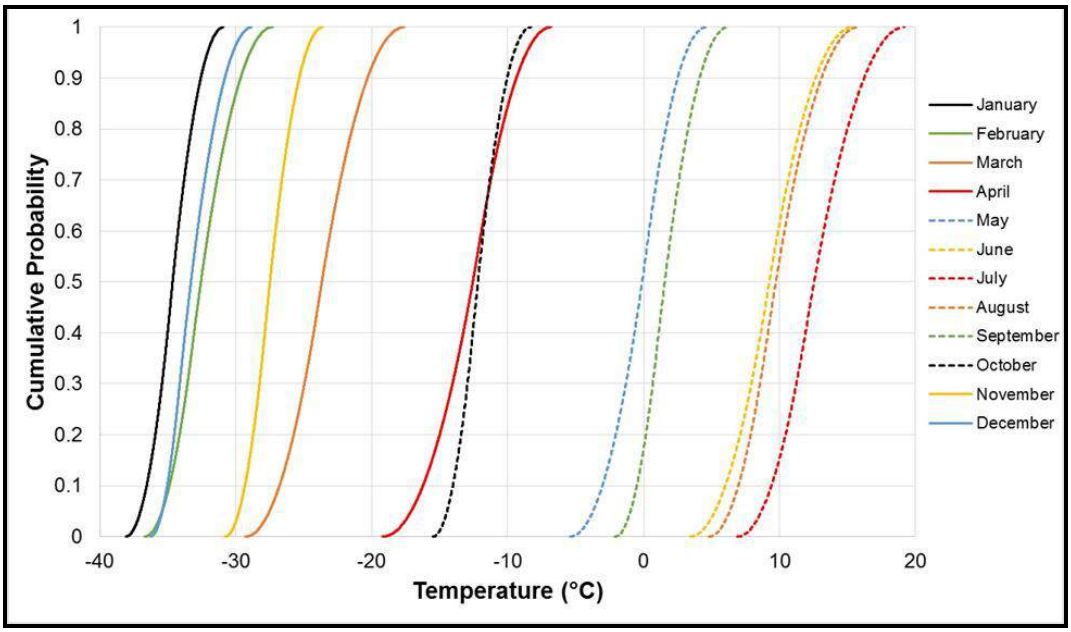
$$T_mode=3*T_avg-(T_min+T_max)$$

The resulting monthly temperature modes, minima, maxima and averages for each triangular distribution are provided in Table 18.16. The resulting temperature distributions are shown in Figure 18.31.

**Table 18.16 Average Monthly Temperature Statistics (°C) for the Syuryen-Kyuyel Meteorological Station**

| Month | Minimum | Mode | Maximum | Average |
|---|---|---|---|---|
| Jan | -38.1 | -34.8 | -30.9 | -34.6 |
| Feb | -36.7 | -33.2 | -27.3 | -32.4 |
| Mar | -29.3 | -23.9 | -17.6 | -23.6 |
| Apr | -19.2 | -12.1 | -6.8 | -12.7 |
| May | -5.4 | 0.2 | 4.6 | -0.2 |
| Jun | 3.4 | 9.1 | 15.4 | 9.3 |
| Jul | 6.9 | 12.0 | 19.2 | 12.7 |
| Aug | 4.8 | 9.1 | 15.8 | 9.9 |
| Sep | -2.1 | 1.0 | 6.2 | 1.7 |
| Oct | -15.5 | -12.5 | -8.3 | -12.1 |
| Nov | -30.8 | -27.8 | -23.6 | -27.4 |
| Dec | -36.3 | -34.2 | -28.8 | -33.1 |

**Figure 18.31 Average Monthly Temperature Distributions**




Precipitation falling within the pit footprint is assumed to be pumped to the WRD sedimentation pond within 24 hours of precipitation events and will be discharged to the surrounding environment (Appendix C). Therefore, precipitation is not included as an input to the WBM.

### 18.12.2 SURFACE WATER

Surface water inputs used in the WBM include the Sirelendge River's mean annual discharge and the proportions of this discharge which occur during each month. OOO ISKOM (2015) presented estimates of five percentiles of the mean annual discharge of the Sirelendge River near the Project site. These percentiles were derived from a generalized (i.e., three-parameter) gamma distribution. To generate a full distribution for use in the GoldSim WBM, a generalized gamma distribution was fit to these five percentile values. The recreated distribution (R2 = 0.99966) and the five percentiles from OOO ISKOM (2015) are shown in Figure 18.32. OOO ISKOM (2015) also provides estimates of the monthly distribution of streamflow for an analog river near the Project site (Dulgalakh River at Syuryen-Kyuyel; Table 18.17). These percentages were used in the WBM to divide the Sirelendge's annual discharge between the five months when the river is likely to be flowing.

**Figure 18.32 Comparison of the Mean Annual Sirelendge River Discharge Distribution used in the WBM and Select Percentile Values from OOO ISKOM (2015)**

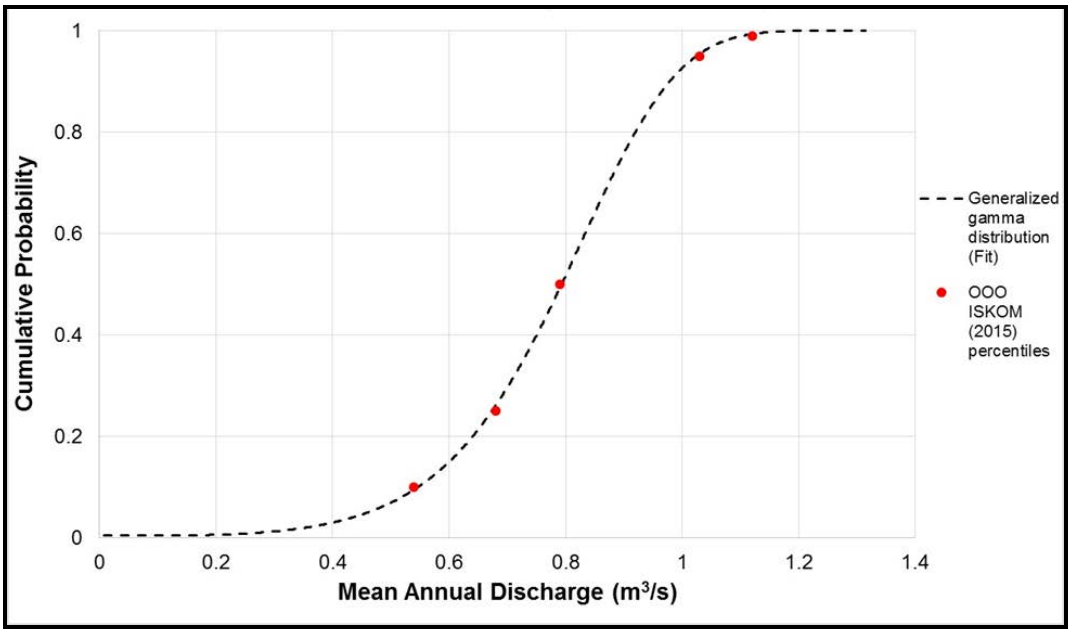



**Table 18.17 Percent Mean Annual Flow during each Month, Dulgalakh River at Syuryen-Kyuyel**

| Month | Percentage of Mean Annual Flow (%) |
|---|---|
| Jan | 0.00 |
| Feb | 0.00 |
| Mar | 0.00 |
| Apr | 0.00 |
| May | 0.00 |
| Jun | 34.00 |
| Jul | 25.80 |
| Aug | 28.30 |

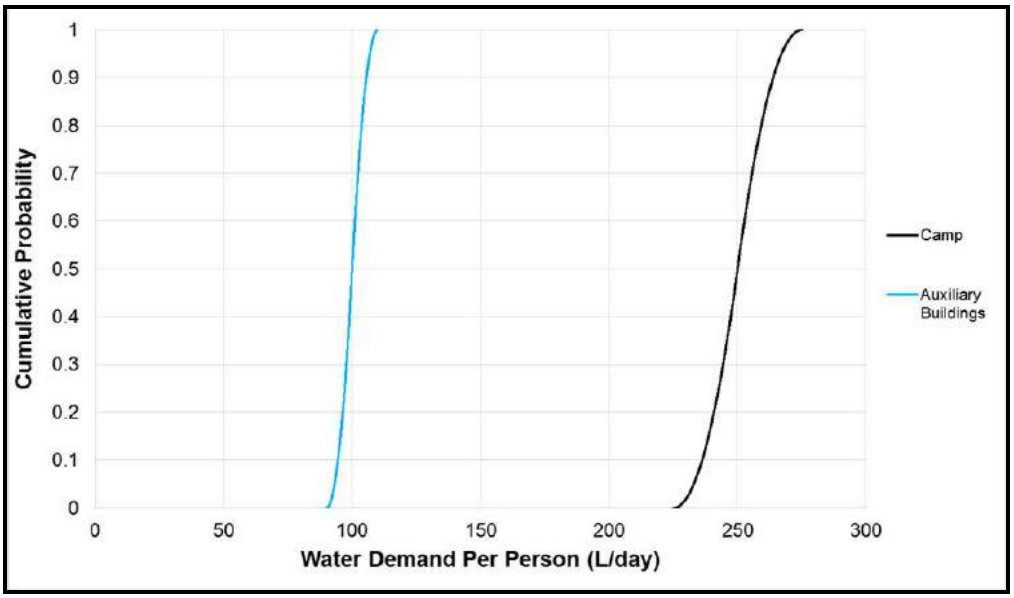
*table continues...*

| Month | Percentage of Mean Annual Flow (%) |
|---|---|
| Sep | 9.53 |
| Oct | 2.37 |
| Nov | 0.00 |
| Dec | 0.00 |

### 18.12.3 PROJECT STAFF

The model inputs related to human water use demand include the number of on-site workers present during the LOM, and the estimated per-person water demands at the camp and auxiliary buildings. The total number of workers present throughout the LOM were based on the open pit and underground labour force estimates developed for the Project feasibility study (Appendix C). The per-person water demands for the camp and auxiliary buildings are estimated by Tetra Tech to be 250 l/d/person and 100 l/d/person, respectively. To account for variability and uncertainty in these estimates, the WBM assumes these values are the modes of triangular distributions, and that the minimum and maximum water demands vary from these values by 10%. That is, the camp water demand will vary from 225 to 275 l/d/person and the auxiliary building demand will vary from 90 to 110 l/d/person. These distributions are shown in Figure 18.33.

**Figure 18.33 Human-use Water Demand Distributions used in the WBM**




### 18.12.4 ORE PROCESSING

The model inputs related to ore processing (milling) include the rate at which ore will be milled, the water required per ton of ore being milled, and the amount of water that is lost during ore processing. The monthly milling schedule developed during the feasibility study (Appendix C) was used to define the milling rate in the WBM. Tetra Tech staff estimates that the ore processing water demand will be 200 to 260 $m^3$/d

at the expected milling rate (9,160 tons/mo). The WBM assumes a uniform distribution from 200 to 260 $m^3$/d for the water requirement at this base milling rate. The unit water requirement (i.e. water volume per ton of ore) is then calculated by the WBM using the value sampled from this distribution and the base milling rate. The two primary sources of water loss during ore processing are expected to be loss to residual tailings water (which cannot be removed during tailings filtration), and other process-related losses. Tetra Tech staff estimates that 12 to 15% of process water will be lost to filtered tailings and 1 to 3% will be lost for other reasons. Uniform distributions were assumed for both of these variables resulting in a total loss of 13 to 18% of process water.

### 18.12.5 Subsurface Mining

The final set of model inputs are related to subsurface mining operations. The mining report for the feasibility study (Appendix C) specifies that the summer and winter water requirements for drilling and watering down the ore will be 176 $m^3$/d and 138 $m^3$/d, respectively. To account for variability and uncertainty in these estimates, the WBM assumes that each of these requirements is the mode of a triangular distribution, and that the minimum and maximum water demand will vary from these values by 10%. As a result, the summer underground water demand varies between 158.4 to 193.6 l/d/person and the winter demand will vary between 124.2 to 151.8 l/d/person. SRK also estimates that during the summer up to 60% of the service water will be recoverable depending on ground conditions and rock temperature. The WBM assumes a uniform distribution from 40 to 60% for the fraction of underground process water that will be reused in summer, which accounts for uncertainty in SRK's upper bound 60% estimate.

The mining report for the feasibility study (Appendix C) indicates that underground mining operations will begin in January 2019 and continue through December 2023. The final input to the WBM is a binary time-series indicating whether or not underground mining is actively occurring during the LOM period.

### 18.12.6 Calculations

The model inputs presented in the previous section are combined with a number of necessary simplifying assumptions to determine the Project water balance. During each model simulation (realization) the same sequence of logic and calculations are performed using different combinations of input parameters. The first step in the model calculations is identifying the amount of surface water available for ore processing and/or subsurface mining operations. Because the current mine plan does not involve collecting runoff from the plant area, little or no dewatering of the underground mine is expected, and pit runoff will be pumped to the WRD sedimentation pond and discharged to the surrounding environment, all three of these quantities are defined as zero in the WBM. Therefore, the Sirelendge River is currently the only source of surface water for the Project.

The Sirelendge River is assumed to have no storage capacity, and the river will only be a usable water source throughout the LOM at the concurrent river discharge. Therefore, surface water is assumed to be only available from June through October.

The second step of the model calculations is to calculate the amount of surface water that can be used for ore processing. The demand for new (i.e., not recoverable and reused) ore processing water is calculated using the actual milling rate, the rate of water consumption per ton of ore, and the fraction of process water that can be reused. If the new water demand exceeds the surface water supply (Sirelendge discharge), then the difference is made up by groundwater. Otherwise, all of the ore processing new water demand is met by Sirelendge River water.

The third group of model calculations determines partitioning of the remaining surface water (if any) for underground mining purposes. Underground demand is calculated based on whether or not underground mining is actively occurring, the monthly average temperature, the summer and winter underground water demands, and the fraction of underground process water that will be reusable in summer. If underground mining is not active, the water demand is always zero. However, after underground mining begins in January 2019, if the average monthly temperature exceeds 0°C, then the underground new (i.e. not reused) water demand is defined by the following equation:

*Underground New Water Demand (t) = Summer Demand* (1- Summer Underground Reuse Fraction)*

Alternatively, if the monthly average temperature is below 0°C, then the underground new water demand equals the winter underground water demand.

As with the logic applied to meeting the ore processing water demand, if the underground new water demand exceeds the remaining surface water supply (Sirelendge discharge minus ore processing new water demand), then the difference is made up by groundwater. When the remaining Sirelendge discharge exceeds the underground new water demand, all of this demand is met by the Sirelendge River.

The final set of calculations calculates the total groundwater demand. The total groundwater demand is the sum of the human demands and the portions of the ore processing and underground mining demands that are unmet by the Sirelendge River. As a result, all water for human use is assumed to be reliant on groundwater throughout the entire LOM. This assumption was made to ensure that the direct, personal needs of Project staff are not dependent on the uncertain availability (and quality) of local surface water resources. The total groundwater demand is the main output desired of the WBM.

### 18.12.7 Outputs

The quantities of greatest interest calculated by the model are the total groundwater demand, the individual components of groundwater demand, the total surface water supply, the rates of surface water use for ore processing, and subsurface mining operations, and the excess available surface water.

Model results are presented and discussed in the following sections.

### 18.12.8 Assumptions

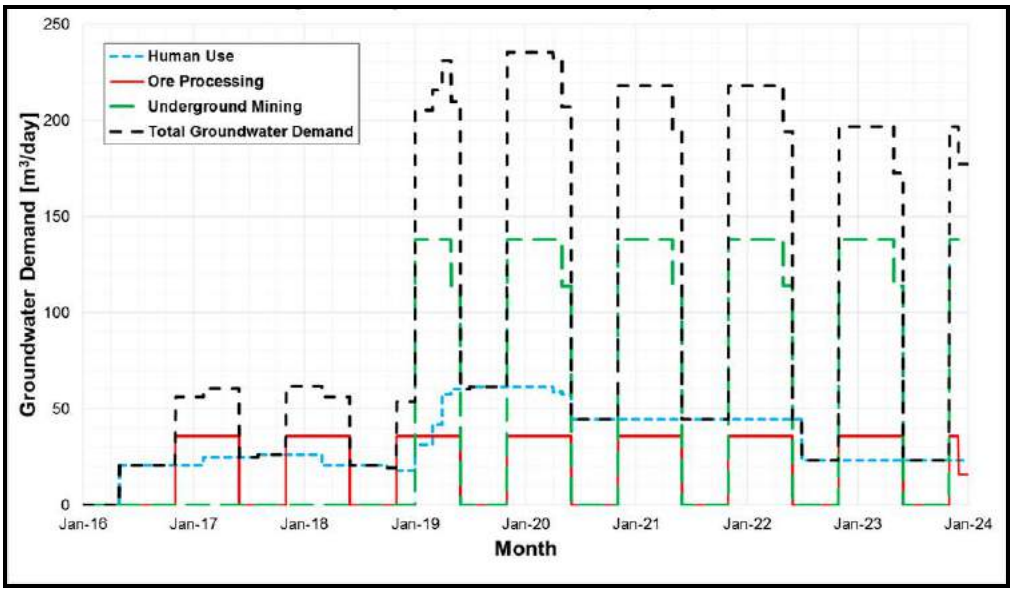
Several assumptions were made in the WBM based on field observations or assumptions made by others. These assumptions are as follows:

- Groundwater flow into the open pit or underground workings is negligible. This assumption is based on the observation that permafrost exists below the proposed mining depth of approximately 300 m (SRK Report Appendix C).
- Drilling in the open pit will not introduce water in the pit. This assumption is based on the proposed method of using compressed air for flushing (SRK Report Appendix C).
- Precipitation falling within the pit footprint is pumped to the WRD sedimentation pond within 24 hours of precipitation events and will be discharged to the surrounding environment (SRK Report Appendix C).
- Runoff from the site will not enter the pit footprint. This assumption is based on constructing diversion structures to reroute surface runoff away from the pit (SRK Report Appendix C).
- Evaporation was assumed to be negligible due to a lack of Project surface water features and freezing conditions that occur approximately eight months of the year.

### 18.12.9 RESULTS

The WBM simulates 10,000 different realizations of conditions during the approximate eight-year (2016 to 2023) life of the Project. Each of these realizations generates a set of the outputs described above during this period, and these results can be viewed individually or summarized statistically. The average total groundwater demand is shown in Figure 18.34 along with the three components that comprise this demand (human uses, ore processing and underground mining). There is a strong seasonal pattern in all of the non-human related demands because when the Sirelendge River is not frozen (i.e., summer) it typically meets all of the new water demands for both ore processing and underground mining purposes. However, the Project will be utilizing groundwater only to meet its demand.

**Figure 18.34 Average Monthly Groundwater Demands Predicted for Human Use, Ore Processing, Underground Mining, and the Cumulative Groundwater Demand from these Sources**




During open pit mining in the first three calendar years of the Project (2016 to 2018), the maximum average groundwater demand is approximately 61.9 $m^3$/d, which occurs in the winter of 2017 to 2018 when all new ore processing water will need to be derived from groundwater and when the number of workers temporarily peaks at 75. The total water demand then rises abruptly in January 2019 when underground mining begins and the number of workers increases from 51 to 90. Since these changes in operations occur during the winter, all of the associated changes in water demands will need to be met by groundwater. The maximum average water demand—235 $m^3$/d—occurs in the winter of 2019 to 2020 when the labour force is at a maximum (176 people), underground mining operations are active, ore continues to be processed, and the Sirelendge River is frozen.

Table 18.18 presents the annually-averaged total groundwater demand, the median (50$^{th}$ percentile, or "P50"), and other select percentiles. A statistical summary of the monthly total groundwater demand time-series is shown in Figure 18.35.

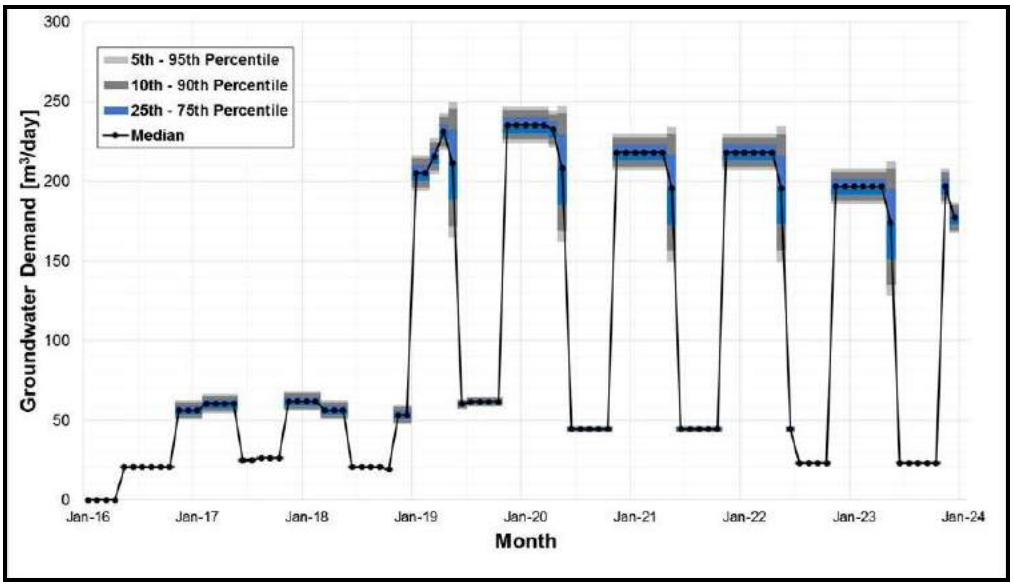
The annual cumulative total groundwater demand statistics in Table 18.18 reveal that the greatest amount of groundwater usage will likely occur in 2019, when approximately 52,000 to 60,000 $m^3$ of groundwater will be required.

The monthly median values shown in Figure 18.35 fall within 1% of the average values shown in Figure 18.34. The greatest variability in predicted monthly total demand occurs in May of each year, when the average temperature varies from -5.4 to 4.6°C and the amount of underground process water reuse can vary widely from 0% (i.e. temperature below 0°C, and reuse is not possible) to 60%. The highest 95$^{th}$ percentile groundwater demand is 249.9 $m^3$/d, which occurs in May 2019. Therefore, it can be stated with greater than 95% confidence that, given the WBM's inputs and assumptions, the monthly average groundwater demand will not exceed 250 $m^3$/d during the life of the Project.

**Table 18.18 Average and Select Percentiles of the Cumulative Annual Groundwater Demand**

| Year | Annual Cumulative Total Groundwater Demand (m³) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | P5 | P10 | P25 | P50 | P75 | P90 | P95 | Mean |
| 2016 | 6,674 | 6,778 | 6,979 | 7,229 | 7,484 | 7,698 | 7,811 | 7,234 |
| 2017 | 15,241 | 15,512 | 16,037 | 16,695 | 17,370 | 17,940 | 18,246 | 16,713 |
| 2018 | 13,788 | 14,049 | 14,557 | 15,195 | 15,849 | 16,400 | 16,694 | 15,212 |
| 2019 | 52,020 | 52,735 | 54,179 | 56,003 | 57,772 | 59,106 | 59,754 | 55,959 |
| 2020 | 51,067 | 51,762 | 53,163 | 54,934 | 56,659 | 57,966 | 58,603 | 54,896 |
| 2021 | 48,507 | 49,186 | 50,573 | 52,340 | 54,052 | 55,331 | 55,948 | 52,297 |
| 2022 | 44,730 | 45,386 | 46,720 | 48,411 | 50,050 | 51,282 | 51,877 | 48,369 |
| 2023 | 40,353 | 40,972 | 42,261 | 43,923 | 45,534 | 46,725 | 47,289 | 43,883 |

**Figure 18.35 Median and Percentile Ranges for the Predicted Monthly Total Groundwater Demand Time-series**




## 18.13 WASTE AND SEWAGE

Regulations state that waste on site is not allowed to be disposed of by burning. Solid waste will be stored in the solid waste storage facility, located to the west of the processing facility, between the reagent storage and ROM pad. The solid waste storage facility will be lined and segregated to handle different waste streams.

A containerised sewage treatment plant will be located at the camp. Sewage from the processing facility washroom facilities will be trucked to the camp sewage treatment plant for processing. As detailed in Section 18.12.3, daily water requirements are in the region of 350 l/d/person, generating approximately 35 m³ of clean waste water from the sewage plant. When the Sirelendge River is flowing, the clean treated waste water will be discharged into the Sirelendge River and the solid, treated cake will be trucked to the TMF and stored with the tails. During periods that

the Sirelendge River is not flowing, the clean, treated, waste water will be taken by bowser to the TMF for storage where the effluent will be treated as TMF runoff.

## 18.14 SITE STORAGE

### 18.14.1 REAGENT STORAGE AND HANDLING

Due to the accessibility to site and the constraints of the winter road only accessible for a short season, reagents will be stored in bulk with a minimum capacity of a nine-month supply.

Reagents will be transported to site in shipping containers and stored in a dedicated fenced secure storage area. The containers will sit on a lined pad that will contain drainage channels and sumps to catch surface runoff, which will be sent for treatment.

The containers will remain closed and locked until they are within the appropriate process plant reagent mixing facility for unpacking where appropriate ventilation and personal protection equipment is available for workers to unpack the container. Empty containers will be sealed and sent back to the reagent supply company for refilling. This is particularly relevant for the cyanide containers which cannot be repurposed and would be difficult to dispose of. The main plant reagents and yearly usage are shown in Table 18.19.

**Table 18.19 Reagent Usage**

| Reagent | Quantity (t/a) |
|---|---|
| Cyanide | 500 |
| Hydrated Lime | 100 |
| Flocculent | 5 |

The cyanide mixing area within the plant will store a small quantity of cyanide for continued operational supply. The cyanide mixing area will be a ventilated enclosed room with concrete floor, bund wall and sump. The mixing area will include sealed bag breaker, agitation tanks and pump systems.

The lime mixing area will include agitation tanks and pump systems all in an enclosed bunded area.

### 18.14.2 EXPLOSIVES STORAGE AND HANDLING

An explosives plant and storage facility will need to be constructed on site to meet the annual explosives and initiation product requirements. The explosives plant will be constructed from the specification and supervision of the explosives supplier. The location of the plant is south of the camp, down the Sirelendge River valley, an appropriate distance to maintain the recommended safety zone from the camp and occupied buildings. The plant is expected to have separate bunkered magazines for containerised storage of ammonium nitrate and initiation devices, office, workshop, and change room facilities.

The ammonium nitrate bags will be moved about the facility using a telehandler. The mobile manufacturing unit will be filled by driving onto a concrete apron adjacent to the store and the bags will be lifted over the truck and the ammonium nitrate discharged from the bottom of the bag. All waste will be adequately stored and disposed of in an appropriate manner in the explosives waste facility located further to the south down the valley.

The bunkered magazines will be placed a safe distance from the rest of the plant and from one another to ensure a safe and secure location for the high explosive and the initiation devices. The dimensions of the earth walls around the magazines will be provided by the explosives supplier; these are to contain any uncontrolled initiation and to minimise danger to plant personnel and infrastructure.

The explosives plant will be contained within a high-security fence. The access will via boom gate at the entrance which will be manned by security guards. Only limited personnel will be authorised to enter the facility and the materials made available will be controlled by the permanent security personnel. The components of the plant will be connected by a maintained gravel road.

### 18.14.3 Fuel Storage and Handling

Diesel and lubricants will be transported from a storage facility in Batamai during the winter road season. For construction and start-up, fuel bladder storage will be used. Each bladder can contain 250 $m^3$ of diesel. Permanent 12 m diameter by 12 m steel storage tanks will be constructed in the fuel farm at the process facility to store 6,000 $m^3$ of diesel, with bladder storage available for the remaining 400 $m^3$ of the nine-month supply volume.

A breakdown of fuel consumption and hence, storage required is shown in Table 18.20. Almost all of the diesel supply will be consumed by the process power station.

A refuelling point next to the fuel storage will be constructed to allow mine fleet and light vehicles to fuel up in a specially equipped area to contain spillage. Spent fuel and lubricants will be drained and stored in drums or approved vessels at a designated area of the fuel storage facility.

**Table 18.20 Maximum Yearly Fuel Consumption**

| Energy User | Power Use (kWh/a) | Fuel Consumption (l/a) |
|---|---|---|
| Process Power Station | 16,206,000 | 4,213,560 |
| Camp | 205,000 | 53,300 |
| Raw Water Supply | 184,000 | 47,840 |
| Mine | 4,953,231 | 3,087,244 |
| Plant Vehicles | 0 | 9,600 |
| Camp Vehicles | 0 | 9,600 |
| **Total Annual Consumption** | **21,548,231** | **7,421,144** |
| Contingency (15%) | 3,232,235 | 1,113,172 |
| **Total Design Consumption** | **24,780,466** | **8,534,316** |
| Nine Months of Storage | | 6,400,737 |

### 18.14.4 Site Storage Closure Plan

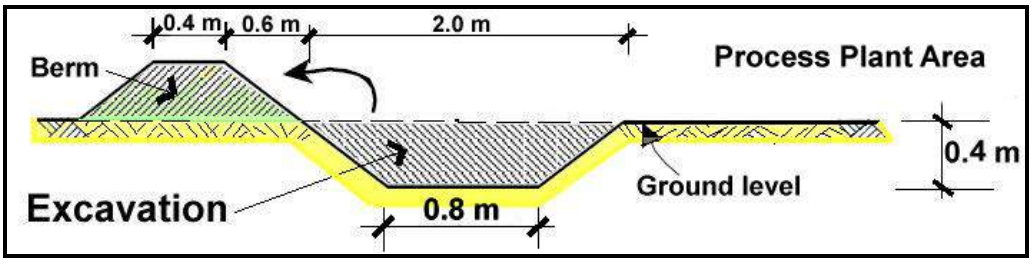
Procurement planning will ensure that the remaining levels of reagents, fuel, and explosives on site at the end of operations are kept to a minimum. A small quantity of fuel and reagents will remain on site for services such as the water treatment plant, which will continue to operate after mine closure. Any small quantities of cyanide will be neutralised and stored within the TMF. Left over ammonium nitrate will be used to fertilize the remediation sites. All other fuel and reagents will be stored at the waste storage facility in sealed barrels. Explosive primers will be properly disposed of in the explosives disposal facility.

## 18.15 Site Services

### 18.15.1 Plant Site Surface Water Management

The process plant is proposed for construction on the top of the plateau, as shown in Figure 18.4. The anticipated amount of precipitation is negligible, and no runoff water will be flowing toward the plant area. During the very short thaw period, the negligible amount of precipitation within the small plant site will be collected in a perimeter ditch, excavated around the structures, and the collected water be conveyed to the nearby TMF. The suggested cross section of the perimeter ditch is shown in Figure 18.36.

**Figure 18.36 Suggested Cross Section of the Runoff Water Collection Ditch**




### 18.15.2 Raw Water Supply

A raw water pump station, located in the Sirelendge River valley next to the camp, will provide the site raw water requirements from a groundwater borehole. A borehole pump located inside the station will pump well water into a 25 $m^3$, heated and insulated tank located adjacent to the station structure. A horizontal multiple-stage centrifugal pump, sized for 45 $m^3/h$ at 540 m of head, will pump water from the pump station tank to the raw water tank located at the processing facility.

The pipe line between the pump station and the mill will be routed up the Porfirovy Valley alongside the access road before leaving the road to head north up the valley. The pipe line will meet up with the access road adjacent to the WRD and continue across the top of the hill to the process plant.. The overall length of the pipe line will be approximately 4.5 km, and an elevation rise of approximately 400 m. Due the high static pressure, the lower half of the pipe will be constructed of carbon steel. The steel pipe line will be supported on wooden sleepers every 3 m, anchored directly to the bedrock or using pilings as required. The sleepers will be manufactured at the site lumber yard, using locally sourced timber. Expansion loops will be located every

250 m. The upper portion of the pipe line will be constructed of HDPE pipe and will be surface run and stabilized with berms every 30 m. The pipe line will be insulated and heat-traced.

Electricity for the pump station will be provided by a 400-V, three-phase, 60-Hz, 645-kW containerised diesel generator, shared with the camp. Switchgear, motor starters, lighting board, heat trace panels, communication panels, UPS and other electrical equipment will be located in a heated electrical room. The generator fuel tank will be located outside and will be sized to store a week of fuel at full load consumption, approximately 30 $m^3$.

The preliminary estimation for power requirements for the pump station are shown in Table 18.21.

**Table 18.21 Pump Station Power Requirements**

| Service | Power Requirements (kW) |
|---|---|
| Borehole Pump | 75 |
| Raw Water Supply Pump | 250 |
| Tank Heating | 15 |
| Lighting and Distribution | 1 |
| Heat Tracing | 75 |
| **Total** | **416** |

The pump station will be heated using heat recovery off the generator and infrared heaters. Monorails will be located in the pump room to service equipment.

The pump station building will consist of two fire rated rooms: the pump room and electrical room.

### 18.15.3 Process Water Tank

The process water tank will be located next to the cyclone tower and ball mill within the process plant. The location of the process water tank was chosen because of the proximity to the processes that require the largest quantity of water addition.

The process water tank will be topped up with fresh feed from the raw water tank and process return feed as barren solution from electrowinning. The process water tank is a 4 m diameter by 4 m fabricated steel tank with sloped tank bottom to allow for periodic cleaning of the settled solids, which will occur small quantities due to the nature of the recycled process water.

### 18.15.4 Potable Water Treatment

Raw water will be processed through a containerised potable water treatment plant to provide potable water. Two treatment plants will be installed on site, one located at the processing facility adjacent to the raw water tank, and one located at the camp to provide potable water for the camp.

The exact specification of the treatment required will be determined by the results of the borehole water tests, but is likely to be a contain filtration, softening, and demineralization processes.

### 18.15.5 Assay and Metallurgical Laboratories

A metallurgical and a geological laboratory will be available on site.

The metallurgical laboratory will be a containerised laboratory located within the process plant and will handle approximately 10 samples per day. The metallurgical laboratory will include the following equipment:

- laboratory jaw crusher
- laboratory roll crusher
- riffles
- samplers
- sieve shaker
- laboratory ball mill
- bench flotation cell
- bottle roll equipment
- titration equipment
- laboratory pressure filter.

The geological laboratory will be located within the camp area, within close proximity to the core logging building. The geological laboratory will process the wet chemical assays from the mine, process plant, and exploration. Tetra Tech estimates that 12 grade control geological samples will be assayed daily.

### 18.15.6 Communications

The site wide data and voice telecommunications for the Project will be provided by a Russian cellular network provider. Silver Bear will install a mast on the hill to the south of the main pit and to this, the cell phone company will install their equipment and infrastructure.

The site local area network (LAN) will connect to the cellular network for datalink to the World Wide Web.

The communications systems for the Project will include:

- telephone system
- two separate LAN networks and datalink to the world wide web
- television surveillance system
- loudspeaker and alarm communications systems
- telecommunications cabling to all buildings

The LAN network is to include all cabling, equipment and infrastructure for connection to each building within the process plant area and to remote sites.

Cellular mobile telephones and communication equipment will provide the functions usually covered by site very-high frequency (VHF) radio. The cellular mast and transmission equipment will be installed and maintained by the cellular network provider.

### 18.15.7 Site Security

Pedestrian and vehicular access to the site will be controlled to provide security for personnel and property and to manage the risk of injury at the mining and processing operations.

The remote location of the site, and the site topography, eliminate the need for full perimeter fencing; however, high risk areas such as the explosives facility, reagent and cyanide storage and the power station will be need to be locally fenced.

Whilst the majority of personnel on site will be operational staff, consideration must be given to the seasonal nomadic reindeer herders that pass through the area.

### 18.15.8 Operational Personnel Transport

Site personnel will be transported around site, between the camp and process facility, and between the camp and airstrip by two rough terrain personnel carriers, each with a capacity of 10 people excluding the driver.

During each shift change-over, 50 to 55 people will have to be transported to the facilities on the top of the hill which will require 3 to 4 round trips per shift. Mining, processing and engineering services shift change overs will be staggered by 30 minutes to accommodate the 30 minute round trip from the camp to the top of the hill.

## 18.16 Power Supply and Distribution

### 18.16.1 Power Supply

Tetra Tech estimated that five, 645 kW diesel generating sets will be required to meet the load requirements of the process plant site.

The estimated operating load and maximum demand are listed in Table 18.22.

The recommended number of generators takes into account the calculated load, a spinning reserve allowance (20% of generator capacity), and an allowance for one cold reserve. The spinning reserve allows for a planned maximum generator loading of 80% following the requirements of Russian standard practice as advised by EMC Consultants.

Containerised generating sets are preferred; however, some assembly may be required on site due to a 14 t site road weight limit.

**Table 18.22 Estimated Load Summary**

| Description | Units | Quantity |
|---|---|---|
| Estimated Average Power | kW | 1 850 |
| Estimated Maximum Demand | kW | 2 200 |
| Generator Capacity | kW | 645 |
| Spinning Reserve (per generator) | kW | 130 |
| Generators Required for Normal Operation (includes spinning reserve) | - | 4 |
| Cold Reserve | kW | 645 |
| Total Number of Generators Required | - | 5 |

Heat recovery from the generator exhaust will be used for building heating.

Remote sites such as the camp facilities are by separate power generation. These are listed in Table 18.23. The mine power requirements will change when underground mining commences. Tetra Tech advised that the underground mine is not critically dependent on heaters, pumps or winders and that power outages could be tolerated. The estimated operating load and maximum demand for the underground mine are listed in Section 16.0.

**Table 18.23 Estimated Remote Site Loads**

| Description | Load (kW) |
|---|---|
| Camp | 150 |
| Mine | 40 |
| Raw Water Pump Station | 416 |
| TMF | 40 |
| Explosives Storage Facility | 40 |

## 18.16.2 Power Distribution

The power station is located adjacent to the process plant building. The generating sets will feed directly on to a 400-V switchgear assembly, which will be located in an air-conditioned, prefabricated building included within the power station package scope of supply. The power station switchgear assembly will contain feeders for distribution of power to the MCCs within the process plant building and for power station services as required.

Power will be reticulated throughout the building on cable ladder attached to building supports or process equipment walkways and support structures.

Three phase low-voltage supply to motors and other services will be 400 VAC.

### *Motor Control Centres*

The low-voltage MCCs and distribution boards will be fully installed in air-conditioned containerised buildings prior to shipment to site. Each room will be maintained at temperatures in the range of 10°C (winter) to 30°C (summer) with suitable air

conditioning and heating. The buildings for the MCCs and low-voltage distribution boards will be mounted 1 500 mm from the finished ground level to allow bottom entry access for all cabling.

Low-voltage variable speed drives (VSDs) will be supplied as part of the low-voltage MCC package. All VSDs supplied will eliminate low-order harmonics using either an active rectifier or a mains passive filters

### *EARTHING*

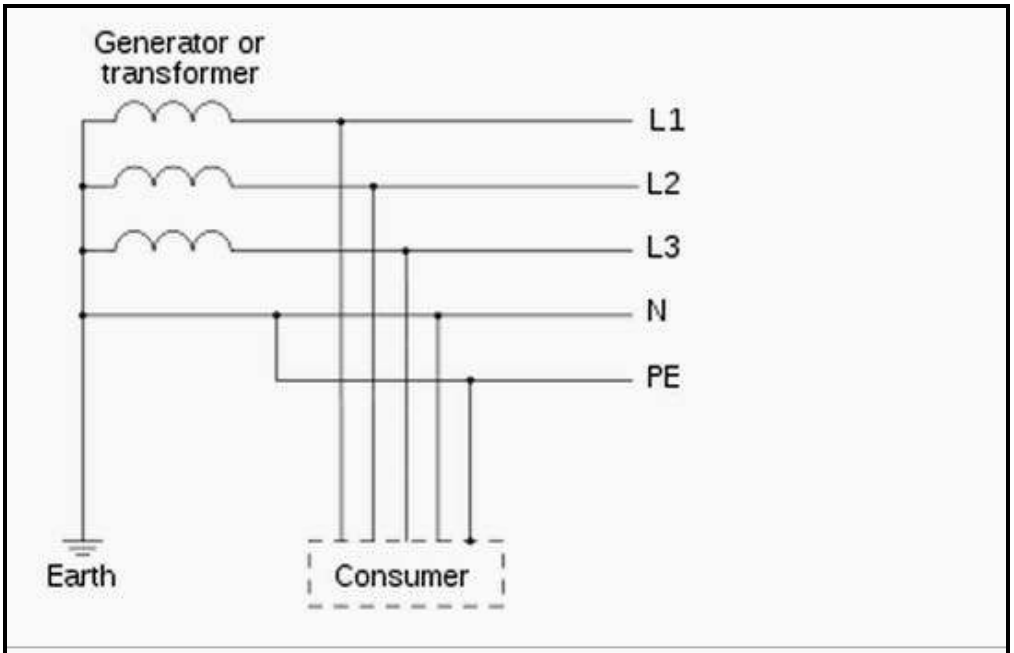
The earthing system will be a "TN-C-S" system as defined in International Electrotechnical Commission (IEC) 60634 (Figure 18.37).

The main earthing electrode system comprises localised earth grids and electrodes around the generators and main switchroom tied by means of poly vinyl chloride (PVC) insulated 120 mm² copper cables to the switch room main earth bar.

The underground earth grid will be installed around and below the generators to prevent dangerous step and touch potentials developing under fault conditions.

Rods will be driven in sufficient numbers and to sufficient depth to achieve less than 1 ohm for substations/MCC rooms and less than 10 ohms at connection points for lightning protection.

**Figure 18.37 Earthing System**




**TN-C-S earthing system**: combined PEN conductor from transformer to building distribution point, but separate PE and N conductors in fixed indoor wiring and flexible power cords.

### 18.16.3 Cables

Cables will be sized and selected according to IEC 60364. Cables will be installed on heavy duty, galvanised cable ladder mounted on building and support structures. All cables will have steel wire armour protection.

### 18.16.4 Lighting and Small Power

Roadway and plant lighting will be installed throughout the plant for 24-hour operation.

Small power outlets will be provided throughout the plant. Lighting and small power distribution boards will be located in electrical rooms and plant areas and these will distribute power at three phase and single phase voltage as required.

### 18.16.5 Vendor Packages

The plant will have a number of vendor packages to be installed. Vendor packages will in general be supplied with electrical equipment such as motors, and heaters pre-installed. The electrical interface with each package will be designated during detailed design.

# 19.0 MARKET STUDIES AND CONTRACTS

## 19.1 PRODUCT

The Project will produce a silver powder of approximately 99.8% purity. Options exist to either smelt this powder into upgraded quality silver doré bars, or to leave it as powder. Both options will require refining before being available for sale as bullion. The Project plans to produce approximately 2.5 Moz (78 Mt) of silver per annum.

Smelting, should that option be selected, would be done in Yakutsk, and not on site, in order to save on power and staffing requirements at the mine site. The ability and willingness of refineries to accept silver powder was therefore tested. Both Russian and international refineries would accept either the high-grade powder or doré. Hence, the option exists to not purchase the smelter and associated equipment. This would save capital and operating costs, operating and security staff, and physical, secure facilities.

## 19.2 MARKETS

There are international banks and precious metal traders who will pay spot prices flat, or less a small percentage discount. For example, Metalor in Switzerland would take silver doré at the flat, spot rate (normally London Bullion Market Association (LBMA) fixing), whereas Sberbank in Russia will take a 0.75% discount. Both institutions have provided some written offers to this effect; however, no contract negotiations have progressed beyond this expression of interest.

The advantage of using Metalor is that they will buy silver powder or doré directly, and refine and buy it with 85% of agreed purchase values paid upon acceptance of the silver at the place of handover, which could be the process plant gates. However, it has become apparent that although not legislated against, it would be extremely difficult to be able to export unrefined product. Indeed, there is a positive drive to keep precious metals within the Russian Federation. In addition to off-take potential by Sberbank, discussions have also been held with Lanta Bank.

Lanta Bank, in Russia, will also contract for the refining and off-take of silver powder or doré, whereas other Russian banks will not. One of the major shareholders of Lanta Bank is Krastsvetmet Refinery—the largest refinery in Russia—and hence Lanta bank can offer the complete collection, transport, refining, and off-take, as well as a series of pricing options. Details of an offer from Lanta Bank are not available at this time, but it is expected to be competitive, as they can provide excellent transport costs due to the volume of precious metals they organise. Lanta Bank is a significant holder and exporter of precious metals.

## 19.3 REFINERY TERMS

Silver Bear has contacted a number of refineries for terms, based on production of a minimum of 60 Mt of silver per annum at a grade of 99.8%, either powder or doré form (Table 19.1).

**Table 19.1 Refinery Terms**

| | Refinery | | | |
|---|---|---|---|---|
| | Metalor | Prioksky | Ekaterinburg | Krastsvetmet |
| Refining Charge ($/oz) | 0.19 | 0.23 | 1.46 | 0.59 |

The wide range of refining charges show that there are some negotiations to follow until a contract can be finalised; however, it does demonstrate that internationally competitive refining charges can be obtained within Russia. It could be expected that a charge of $0.20/oz could be achievable in Russia. A rate of RUB63:00:USD1:00 was used for the Russian refineries noted in Table 19.1. All refineries offer similar overall recoveries.

# 20.0 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

## 20.1 INTRODUCTION

Silver Bear retained ERM to review and summarize the work completed regarding the relevant environmental, social, and regulatory factors for the feasibility study for the Project with an effective date June 9, 2016. At that time, ERM considered the work of others as complete and accurate and commented only on the principles upon which Project infrastructure and facilities have been planned in so far as environmental controls. ERM has not undertaken any engineering design and the plans for, and the infrastructure and facilities required to manage water and waste, were designed, described, and reviewed in other sections of this report.

The feasibility study update for the Project is based on a revised mine plan to reflect the results of a more recent drilling program conducted at the Property. ERM has updated its summary of the environmental, social, and regulatory factors on an assumption that no material changes regarding the interaction between the Project and the natural and social environments are introduced with the revised mine plan. As such, the original review of environmental and social factors completed by ERM is considered to remain accurate.

For the purposes of the update, ERM has summarized the current status of the regulatory factors for the Project based on information regarding permitting provided by Silver Bear. Review of permitting details, including the potential implications of terms and conditions in any permits received by Silver Bear and/or commitments made in updated regulatory applications has not been conducted by ERM. ERM has considered the status of permitting provided by Silver Bear to be accurate.

## 20.2 PERMITTING REQUIREMENTS

This section provides a summary of main regulatory requirements that govern the development, operation, and closure of the Project under Russian law, along with a summary of ERM's understanding of the current permitting status of the Project. It is not the intent of this section to provide a detailed list of regulations that may be applicable.

The simplified permitting process for mining Projects in Russia includes the following stages:

1. obtain mining license
2. confirm resources
3. conduct surveys and studies
4. develop and receive approval of project design documentation

5. obtain permits.

### 20.2.1 Mining License

Mining licenses are granted by the State Authority and outline the resources (quality and quantity of metals to be extracted) and specific conditions for exploration and development. A mining license holder is obliged to follow all the requirements specified in the license.

Silver Bear obtained a license for mining silver, copper, lead, and zinc on the Vertikalnye deposit. The license was issued with a termination date of 1st September 2033.

All the metals noted in the license are required to be extracted under Russian law. The feasibility study includes the mining and processing of ore to extract silver only. Further details regarding mineral tenure are described in Section 4.0.

### 20.2.2 Confirmation of Resources

Once the mining license is granted, exploration surveys and preliminary engineering studies must be conducted, as specified by the license. The outcomes of these surveys and studies are used to produce a TEO Conditsy Report (TEO), which is a technical-economical study that specifies conditions for development of the deposit. The TEO needs to include the amount of resources to be extracted, required infrastructure, economic feasibility of the project, and the potential market overview. The TEO is subject to approval by the Russian Central Commission for Reserves, which allows the license holder to initiate the development of the technical design documentation.

Silver Bear developed the TEO Conditsy report and submitted it for approval to Russian Central Commission which has completed its review on April 08th, 2016. A positive conclusion regarding approval was made on April, 25th 2016.

### 20.2.3 Surveys and Studies

Several surveys and studies are required to be conducted for the technical design development and are included as part of the project design documentation.

Necessary surveys include:

- geotechnical surveys
- hydrology, hydrogeology and meteorological engineering surveys
- geological engineering surveys (including surface and ground water surveys for water supply sources)
- environmental engineering surveys.

Silver Bear and its consultants have conducted various studies intended to fulfil these obligations. Survey reports were submitted for State Review process; however, they were not fully accepted by the commission and a number of comments and requirements were provided to Silver Bear by the State. Based on this feedback,

Silver Bear conducted additional surveys during summer season of 2016. Silver Bear anticipates submitting the redeveloped reports in November 2016.

### 20.2.4 Development and Approval of the Project Design Documentation

In accordance with Russian legislation, a mining license holder must develop project design documentation. This documentation can be split into different sections and is approved by separate authorities (e.g. mining/waste management, and processing plant/infrastructure).

Silver Bear developed the mining and waste management sections of the project design documentation, which includes an ESIA for these facilities. These sections were reviewed by the appropriate authorities (Table 20.1 – Stage 1) and positive conclusion of the Environmental State Review was obtained. Work on the process plant/infrastructure section is currently in progress.

In accordance with Russian environmental regulations, an ESIA for process plant/infrastructure is not required; however, it is required for waste management facilities. Following approval of the mining/waste management sections of the project design documentation, Silver Bear can submit the completed project design documentation, including the process plant/infrastructure documentation, for further review by the appropriate authorities (Stage 2). As of the date of this report, the Stage 2 submission has not yet been submitted by Silver Bear and the anticipated date of the submission is unknown. ERM notes that Silver Bear does not intend to include the existing airstrip or the connecting road to the personnel camp in the project design documentation. This is a gap, as the feasibility study includes updates to this infrastructure that require approvals in accordance with Russian legislation.

Table 20.1 describes steps (in chronological order) that have already been performed and still must be completed by Silver Bear in order to obtain the relevant permits to start construction and operation activities in compliance with Russian legislative and regulatory requirements. The dates contained in Table 20.1 were provided by Prognoz, and ERM has not completed an evaluation of the likelihood that these dates can be achieved. Stage 0 refers to permits and approvals which are required but not directly refers to the State Environmental Review and State Review processes. ERM has not completed a detailed review of any terms and conditions associated with permits and approvals that may have been received. As such, there exists the potential for discrepancies between requirements and the feasibility study Project design. Table 20.1 is current as of November 11, 2016, as compared to the effective date of the feasibility study of October 4, 2016.

Should there be a positive conclusion from the State Environmental Review and the State Review, Silver Bear will be in a position to apply for Permit for Construction, as well as for the other required permits, as listed in Table 20.2.

ERM notes that Silver Bear has already commenced and continues construction activities associated with the Project, in advance of design development and obtaining all of the necessary permits. In addition to real or perceived risks to safety and/or the environment, conducting these activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material.

**Table 20.1 Mangazeisky Project Design Documentation Development and Approval Process**

| | Document | Authority | Desired Approval Outcome | Project Status (according to the data provided by Prognoz on 11th November 2016) |
|---|---|---|---|---|
| Stage 0 | Permission for construction of non-hazardous industrial facilities | Non-governmental review (by specialized licensed private company) N | Positive conclusion | Conducted on 22nd July 2016. |
| | Sanitary Protection Zone of groundwater intake | FBHD "Hygiene and Epidemiology Center in Sakha (Yakutia) Republic" | Positive conclusion | Conducted on 11th October 2016. |
| | Groundwater reserves (C1 category) | Committee for Geology and the Use of Subsurface Resources of Sakha (Yakutia) Republic | Positive conclusion | Expected by 15th November 2016. Protocol not received as of the date of this Report. |
| | Justification of License on Subsoil Use | Central Commission for Reserves | Positive conclusion | Conducted on 12th April 2016, Protocol received 28th April 2016 |
| Stage 1 | Mining and waste management section (including TMF, waste rocks and solid wastes landfill) | Public Hearings arranged by Company and local authorities | Protocol of Public Hearings (with positive conclusion) | Conducted on 18th April 2016, Protocol received 17th May 2016. |
| | | Fishery authority of regional level (Lensk Basin Fishery Administration) | Approval in terms of impacts on surface water bodies of fishery significance and the levels of damage and compensationFes | Received by 16th June 2016. |
| | | Federal Supervisory Natural Resources Management Service (Rosprirodnadzor) | Approval of volumes of wastes will be generated by the Project and waste classification with regard to Hazard Classes | Received on 26th October 2016. (as a part of positive conclusion of State Environmental Review) |
| | | State Environmental Review | Positive conclusion | Received on 26th October 2016. |

*table continues...*

| | Document | Authority | Desired Approval Outcome | Project Status (according to the data provided by Prognoz on 11th November 2016) |
|---|---|---|---|---|
| Stage 2 | Russian Design Documentation including the approved by State Environmental Review mining and waste management part and baseline surveys reports | State Review of surveys: geological, meteo- and hydrological, geotechnical, environmental for mining and waste management facilities | Positive conclusion | Adverse opinion was received on 12th August 2016.<br>Resubmitted surveys anticipated to be filed by Company in November 2016. |
| | | Fishery authority of regional level (Lensk Basin Fishery Administration) | Project Approval of impacts on surface water bodies of fishery significance and the levels of damage and compensations | Received by 16th June 2016. |
| | | Federal Supervisory Natural Resources Management Service (Rosprirodnadzor) | Project Approval wastewater discharge points | Outstanding |
| | | State Review | Positive conclusion | Adverse opinion on the set of baseline survey reports was received on 12th August 2016.<br>Silver Bear anticipates submitting the mining and waste section of the Russian Design Documentation in November 2016 with an expectation of approval in January 2017. |
| | | | Positive conclusion with regard to the industrial and environmental safety of the Project design solutions | Application will be possible when positive conclusion of the State Review will be in place. Application date is expected in January 2017. |
| | Explosive and high-toxic substances Transportation authorization | Federal Supervisory on Industrial Safety (RosTechNadzor) | License for transportation and use of explosive and high-toxic substances | Outstanding |

*table continues...*

| | Document | Authority | Desired Approval Outcome | Project Status (according to the data provided by Prognoz on 11th November 2016) |
|---|---|---|---|---|
| Stage 3 | Permission for industrial and domestic waste disposal | Federal Supervisory Natural Resources Management Service (Rosprirodnadzor) | Permission | Expected after the end of the construction and commissioning stages |
| | Russian Design Documentation including and processing plant and infrastructure section (approval of this section by the State Environmental Review is not required). Note: Silver Bear intends to not to include the airstrip and access road from the airstrip from the design documentation which ERM believes is a regulatory gap. | State Review of surveys: geological, meteo- and hydrological, geotechnical, environmental for processing plant and infrastructure | Positive conclusion | Expected application date is not defined yet |
| | | State Service for Public Wellbeing (Glavgosexpertiza) | Approval of the Project in terms maintenance of standards of impacts on workers | Expected application date is not defined yet |
| | | Federal Supervisory Natural Resources Management Service (Rosprirodnadzor) | Project Approval wastewater discharge points | Expected application date is not defined yet |
| | | State Review | Positive conclusion | Expected application date is not defined yet |
| | | | Positive conclusion with regard to the industrial and environmental safety of the Project design solutions | Expected application date is not defined yet |

### 20.2.5 PERMITTING PROCESS

Table 20.2 lists the relevant permits required to be obtained by Silver Bear after the approval of the Project by State Review, in order to conduct construction and operation activities in line with legal Russian Federation requirements.

**Table 20.2 Required Permits**

| Permit Title | Construction | Operation | Status |
|---|---|---|---|
| **Trigger Activity: General Mining** | | | |
| License for subsoil use for the purposes of exploration and mining | √ | √ | Obtained |
| Conclusion of State Environmental Review (Expertize) on the Project design documentation and results of engineering surveys, Conclusion of the State Review in order to apply on Permit for Construction | √ | √ | The conclusion of the State Environmental Review on mining and waste section of the design documentation is obtained. The conclusion of the State Review on mining and waste section is expected on January, 2017. The design documentation of the processing plant is in progress and application date is not scheduled yet. |
| **Trigger Activity: Operating Mining Facilities** | | | |
| Expert Conclusion on Industrial Safety | | √ | Application is expected on January, 2017 |
| Expert Conclusion of on Industrial Safety of Hazardous Facilities | √ | √ | Application is expected in Q1 2017 |
| Permit for each specific type of technical equipment on hazardous facilities | √ | √ | Application is expected in Q1 2017 |
| Fire safety certificate | √ | √ | Application is expected in Q1 2017 |
| Permission for construction reconstruction or major repair of facilities, in cases where subsoil use is required | √ | | Application is expected on January, 2017 |
| Certificate of conformity GOST R (Certificate of Quality) | | √ | Application date is not defined yet |
| **Trigger Activity: Use of Explosives** | | | |
| License for operation of explosion-hazardous production facilities | √ | √ | Temporary permit is obtained (reportedly) |
| License for storage and use of explosive substances for production activities | √ | √ | Temporary permit is obtained (reportedly) |
| Permission to conduct blasting operations | √ | √ | Temporary permit is obtained (reportedly) |

*table continues...*

| Permit Title | Construction | Operation | Status |
|---|---|---|---|
| **Trigger Activity: Waste Generation** | | | |
| Approval of Waste Generation and Disposal Targets (WGDT) | √ | √ | Application date is not defined yet |
| Approval of hazardous wastes certificates | √ | √ | Application date is not defined yet |
| Expert Conclusion of State Environmental Review of design documentation for waste storage and neutralization facilities | √ | √ | Application date is not defined yet |
| License for the neutralization and disposal of Hazards Class I - IV waste | √ | √ | In progress Application date is not defined yet |
| **Trigger Activity: Water Abstraction** | | | |
| License for subsoil use for the purposes of ground water abstraction | √ | √ | Application is with authorities. Decision is expected |
| Decision authorizing use of the water body for wastewater discharge (partially obtained) | √ | √ | Application is with authorities. Decision is expected |
| **Trigger Activity: Environmental Emissions** | | | |
| Approval of Allowable Discharge Rate (for water emissions) | √ | √ | Application date is not defined yet |
| Permit for discharge of contaminants to the environment (water emissions) | √ | √ | Application date is not defined yet |
| Approval of Maximal Permissible Emissions (air emissions) | √ | √ | Application date is not defined yet |
| Permit for emission of contaminants to the atmosphere | √ | √ | Application date is not defined yet |
| **Trigger Activity: Private Aviation** | | | |
| The decision of the State Commission for radio frequencies (SCRF) on allocation of radio frequencies for the use of radio-electronic means | √ | √ | Application date is not defined yet |
| Conclusion of the expertize on the possibility of allocation of radio frequencies | √ | √ | Application date is not defined yet |
| Permission to use radio frequencies (RF channels) of Roskomnadzor | √ | √ | Application date is not defined yet |

*table continues...*

| Permit Title | Construction | Operation | Status |
|---|---|---|---|
| Registration of radio-electronic means in the bodies Roskomnadzor and receipt of a certificate of registration | √ | √ | Application date is not defined yet |
| Certificate of ownership for aircraft | √ | √ | Application date is not defined yet |
| Certificate of registration for aircraft | √ | √ | Application date is not defined yet |
| Certificate of airworthiness of aircraft | √ | √ | Application date is not defined yet |
| Air operator certificate(s) | √ | √ | Application date is not defined yet |

Note: √ - required on the relevant project stage

ERM notes that the Project execution plan and schedule has been de-coupled from permitting activities. Construction activities are being undertaken without the necessary permits in place. Further, the commencement of mining is planned for Q4 2016 and ore processing in Q2 2017, whereas there is a high risk based on the current status that permits will also not be in place to support these operating stage activities by the dates assumed in the FS. In addition to real or perceived risks to safety and/or the environment, conducting these current and future activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material.

Permitting plans exclude the access road between the airstrip and the mine site. ERM is of the view that this is a gap as upgrades to that existing infrastructure forms part of the Project.

Although Silver Bear has received a positive determination of the State Environmental Review for mining and wastes, changes to the Project based on the updated mine plan presented in the FS need to be presented to the authorities to determine if an amendment to the approval is required.

## 20.3 ENVIRONMENTAL AND SOCIAL STUDIES

### 20.3.1 STUDY DESIGN

Environmental and socio-economic studies that have been completed to date and/or ongoing are intended to contribute to the following objectives:

- Characterize the existing physical, biological, and socio-economic conditions to enable an assessment of potential impacts from the interaction with project components and activities, and develop appropriate mitigation and management measures to reduce adverse effects and maximize positive effects. This characterization will also identify and track trends in areas potentially affected by the Project during construction, operation, and closure.

- Characterize the geochemical characteristics of the Mineral Resource extraction process (tailings) and the mine waste that the Project will generate, to develop an understanding of their associated factors that could impact the environment.
- Inform mitigation and monitoring programs that will be implemented during the construction, operation, closure, and post-closure phases of the Project, such that predictions effects can be validated and any unanticipated effects can be iteratively addressed as necessary as the Project proceeds.
- Engage with potentially affected populations through the course of baseline data collection to exchange information on the Project, and to provide local residents, land users, communities, and other stakeholders the opportunity to express their concerns and participate in the ongoing project design and development process.

A list of specific environmental and social studies that have been completed to date are summarized in Table 20.3. These reports are also summarized further in this section.

**Table 20.3 Environmental and Social Studies Completed (as of June 2016)**

| Studies Complete to Date | Date of Surveys | Scope |
|---|---|---|
| **Air Quality and Noise** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report includes results of the one-time air sampling and analysis and noise measurement. Report provides results determination of snow as an indirect method of air quality assessment. |
| **Climate** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report includes description of the general and seasonal climatic characteristic, including main climatic parameters (temperature, moisture, wind, precipitations, etc.). |
| Report on engineering-hydrometeorological surveys within the Mangazeyskoye mine field in Yakutia region of Russia, produced by OOO ISKOM | 2015 | Report includes description of the general and seasonal climatic characteristic based on archive and relevant literature sources. |
| **Surface Water** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report includes review of the archive data and field survey of the hydrological characteristics of the Project area, results of water sampling, field and laboratory analysis. |
| Report on engineering-hydrometeorological surveys within the Mangazeyskoye mine field in Yakutia region of Russia, produced by OOO ISKOM | 2015 | Report includes results of field hydrological and hydro-chemical regime of rivers survey. Description of the hydro-morphological characteristic and hydrological parameters (river flow) of the watercourses. |

*table continues...*

| Studies Complete to Date | Date of Surveys | Scope |
|---|---|---|
| **Geology** | | |
| Report on prospecting work within the central part of silver- polymetallic ore "Mangazeyskoye" mine field, produced by "YanGeologiya" | 1993-2003 | Report includes analysis of mineral resources base of silver within "Mangazeyskoye" mine field based on prospecting work. Report includes description of the geology and permafrost conditions, morphological and geochemical characteristics of the mine field. |
| Report on assessment of acid potential and geochemical properties of waste rock at the Vertikalnoye deposit of the "Mangazeyskoye" mine field, produced by ERM | 2015 | Report contains the interim findings of investigations of waste rock /tailings properties and includes results of the sampling and analysis of mine waste rock, description of the composition of tailings, etc. |
| Seismicity survey conducted by Neryungristroiizyskaniya (NSI) | 2015 | Report contains results of micro shooting and confirmation of seismicity scale of the project area. |
| **Ground Stability and Permafrost** | | |
| Report on engineering-geological surveys of baseline conditions of geological environment within the Mangazeyskoye" mine field in Yakutia region of Russia, produced by State State Unitary Enterprise (SUE) "YakutTISIZ" | 2005 | Geological and geomorphological studies and analysis of hazardous exogenous processes and hydrological phenomena were carried out. This survey allowed gathering detailed information on the geological, geomorphological and cryological features of the Project area, conditions and forms of existence and development of hazardous exogenous processes. |
| Report on engineering-geological surveys of permafrost-hydrogeological, hydrogeological and engineering-geological conditions of Vertikalnoye license area of "Mangazeyskoye" mine field, produced by LLC "NeryungriStroyIzyskaniya" | 2014 | Hydrometric, morphometric and geothermal studies were carried out. Report also includes information on hazardous exogenous processes. |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report includes desktop description of geomorphological and cryological features of the Project area, geomorphological features and development of the hazardous exogenous processes within the design facilities' sites. |
| **Groundwater** | | |
| Report "Assessment of the capacity for groundwater supply of the mining and processing enterprise in the Vertikalnoye deposit of the "Mangazeyskoye" mine field based on the results of geophysical and hydrogeological studies of drilling exploration wells", produced by LLC "NeryungriStroyIzyskaniya" | 2015 | Report includes the results geophysical and hydrogeological studies of drilling exploration wells within the Project area and results of water sampling and laboratory analysis (please also refer to Section 20.5.1). |
| Hydrogeological modeling performed by SRK | 2015 | Report includes the results of hydrogeological modeling performed based on the data of tests on groundwater inflow. |

*table continues...*

| Studies Complete to Date | Date of Surveys | Scope |
|---|---|---|
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report includes review of the archive data and recent survey of the hydrogeological characteristics of the Project area, results of field and laboratory analysis. |
| **Soil** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit (ERM 2016b) | 2015 | Report based on archive and relevant literature sources and assessment of environment of study area based on the field survey. Report includes description of the general characteristic of the soils and results of the sampling and analysis (geochemical, bacteriological, parasitological). |
| **Radiological Conditions** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | Report includes results of the gamma-ray survey, measurement of the maximum GREDR, measurement of the ground surface RFD and natural water sampling to access total specific alpha and beta activity. |
| **Terrestrial Ecosystem** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | Report includes review of the archive data and recent floristic survey (flora and vegetation and their habitats) of the Project area, results of vegetation sampling and laboratory analysis. |
| **Terrestrial Wildlife** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | Report includes review of the archive data and recent biodiversity survey (invertebrates, vertebrates and birds and their habitats) of the Project area, as well as report includes information on protected species. |
| **Aquatic Life including Fish and Fish Habitat** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | Report includes review of the archive data and recent ichthyologic survey (fish and hydrobionts sampling and geochemical analysis) of the Project area. |
| **Specially Protected Natural Areas** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | Report includes current data about the local and regional specially protected natural areas situated in the Project area of impact. |
| **Socio-economic and Land Use** | | |
| Technical report on environmental baseline conditions in the Vertikalnoye deposit, produced by ERM (2016b) | 2015 | The survey combined quantitative (analysis of socioeconomic statistics) qualitative (expert interviews with representatives of local authorities and community; analysis of the qualitative data on the socioeconomic situation from public sources) methods. |

*table continues...*

| Studies Complete to Date | Date of Surveys | Scope |
|---|---|---|
| Report on historical and cultural expertise "Assessment of the impact on the ethnological environment in the places of residence of indigenous people and Archeological study for the construction and operation of facilities of the Vertikalnoye deposit of the "Mangazeyskoye" mine field produced by the Institute of Humanitarian Research and Indigenous Studies of the North (Russian Academy of Sciences, Siberian branch) | 2015 | Report includes survey on identification of objects of archaeological heritage directly on the Vertikalnoye deposit and adjacent areas. |
| Report on ethnic and cultural conditions in Sebyan-Kuel settlement located in Kobyaysky District of Sakha (Yakutia) produced by the Institute of Humanitarian Research and Indigenous Studies of the North (Russian Academy of Sciences, Siberian branch) | 2015 | Report includes desktop and field (questionnaire survey and interviews with representatives of locals) ethnological surveys. |

### 20.3.2 EXISTING ENVIRONMENTAL CONDITIONS

Existing environmental conditions are described based on ERM (2016b) a part of the Russian design documentation. The surveys included field works, laboratory, and desktop studies performed by ERM consultants involving local experts and scientific institutes. Report has been prepared in Russian only.

#### *PHYSICAL ENVIRONMENT*

The Project is located in the Kobyaysky District (Ulus[1]) of the Sakha Republic in a highland with altitudes of 800 to 2,200 masl (Figure 20.1) A seasonal winter road connects the Project to port facilities on the Lena River and the nearest settlement, Sebyan-Kyuel, is 43 km south-southwest of the Project site. The Project area is located within the Endybal River basin and the largest watercourses include the Arkachan, Endybal, Sirilende, and Fedor-Yurege rivers.

The Project is located in an area characterized by a continental sub-arctic climate, and is significantly influenced by the mountain relief that causes high wind velocity in elevated areas. The average monthly temperatures for January and July are −38.1°C and +13,7°C, respectively. The frost-free period lasts for 52 days, on average; however, some years have had frost persisting throughout the entire summer. Precipitation of approximately 200 mm/a occurs mostly as snow. The approximate number of days with snow cover is 209, and the average snow depth is no greater than 35 cm.

Current air quality baseline conditions are below established criteria for carbon monoxide, nitrogen dioxide, sulphur dioxide, and particulate matter. Baseline air

[1] 'Ulus' is an administrative division unit of the Sakha Republic equivalent to a district.

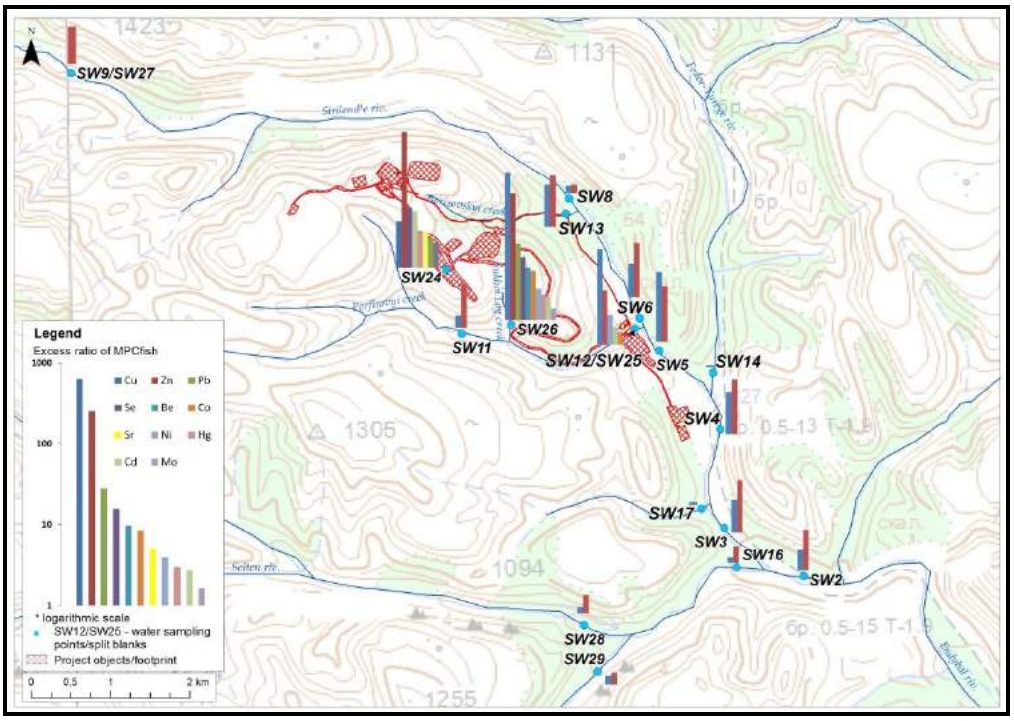
quality in the area is dominated by natural sources and limited to dust from wind erosion, primarily just after snow and ice have melted and under dry conditions. However, available data is limited due to the remoteness of the site and activities limited to ongoing exploration. The air quality in the Project area is within regulatory maximum permissible concentrations (MPC).

The river system in the Project area consists of the Sirelendge River and its major right-bank tributaries: Borisovsky Creek and Porfirovy Creek, with a tributary, Sukhoi Log Creek. This is the basin of the Yana River which flows into the Arctic Ocean.

Preliminary laboratory tests indicate that concentrations of minerals in some surface water samples and bottom sediments exceed regulatory standards (maximum permissible concentrations for fishery water bodies ($MPC_f$[2]). These elevated concentrations (Figure 20.1) are attributed to natural weathering processes across the Project affecting regional watersheds, and to exploration activities in local waterways near the Vertikalny deposit area. The feasibility study does not include an allowance to remediate any historical impacts that may be caused to date by Project activities.

Preliminary analysis suggests elevated concentrations of magnesium, iron, manganese, aluminium, strontium, copper, zinc, cobalt, nickel, cadmium, lead, and selenium in surface water and elevated metal concentrations of cadmium, lead, nickel, zinc, and arsenic in bottom sediments.

**Figure 20.1 Surface Water Quality Compared to MPC for Water Courses for Fishery Water Bodies (MPCf)**




[2] Surface water quality standards are determined in Russia for water bodies dedicated to the corresponding water use: MPCs for fishery water bodies ($MPC_f$) and MPCs for cultural and domestic water use ($MPC_{cd}$)

Terrain of the Verkhoyansk Range is primarily defined by seasonal water erosion during the spring snow melt and storm rainfall that results in eroded low areas separating topographic highs. This seasonal water erosion also defines slope processes in the Project area (Figure 20.3).

Other geological and hydrological processes that affect the Project area terrain include:

- cryogenic, including frost splitting, seasonal heaving, solifluction, deserption, frost sorting, stone-run formation (Figure 20.2), thermokarst
- gravitation: slides, landslides (Figure 20.4), landfalls, mudflows (Figure 20.5), avalanches
- fluvial and hydrological: erosion, swamp formation, and ice formation.

**Figure 20.2 Alpine-type Terrain of the Area along the Axis of the Verkhoyansk Range**

Source: E.V. Garankina

**Figure 20.3 Stone-runs of Small Boulders in Near-the-edge Area of the Right Bank of the Borisovsky Creek Valley**

Source: E.V. Garankina

**Figure 20.4 Micro Landslides on Taluses, Left Bank of the Sirilendie River Valley, Opposite the Workers' Settlement, after a Heavy Rain on 8th August 2015**

Source: E.V. Garankina

**Figure 20.5 Small Mudflow Channel after a Heavy Rain on 8th August 2015 in the Cleavage of the Northern Slope of Mount Endybal**

Source: E.V. Garankina

Permafrost conditions are approximately 230 to 350 m below ground surface, reaching thickness of up to 400 to 500 m on larger plateaus. This is the main factor defining engineering and geological characteristics of the area. Seasonal freezing of the near surface material is relatively fast. On average, it takes two months; freezing speed exceeds 1 cm/d.

Groundwater of the Yana-Indigirka basin consists of two hydrogeological levels:

- perched water, seasonal thaw depth (active zone) water and taliks (under lakes)
- connate water within the cracks and pores of the underlying geologic material below the permafrost zone.

Water within the perched, active zones and talik is insufficient for use at the Project process facility and for drinking due to poor quality and limited/seasonal availability. Additional studies (Table 20.3) confirm the availability and sufficiency of infra-permafrost water to be used for the Project water supply. Based on the work completed by SRK (Section 20.2), and described in Table 20.3, ERM is not aware of any environmental or regulatory constraints preventing the use of this water for this purpose.

### *Biological Environment*

#### *Soil*

Soil in the Project area is poorly developed, acidic, and has a high proportion of stones and debris. The soil is also affected by cryogenic deformation and thixotropic and suprapermafrost gleying resulting in limited soil regeneration.

Common soil types of the area and their associated location and vegetation community are summarized in Table 20.4.

**Table 20.4 Summary of Terrestrial Ecosystem Communities**

| Soil type | Location/Community |
|---|---|
| Typical brown soils | Cowberry-lichen tundra and upper taiga larch open woods at narrow watersheds and steep slopes of the middle taiga zone (10%) |
| Podzolized cryosolic soils | Larch moss-cowberry forests in river valleys |
| Mountain tundra typical and gleyic soils | mountain tundra belt on well drained and poorly drained flat areas |
| Dry-peaty brown and high moor peaty brown soils | Middle and lower parts of slopes under ledum-sphagnous larch woods in river valleys and intermountain nicks |
| Chernozem-like soils | Rare |
| Alluvial soils | Valleys of rivers and creeks |
| Al-Fe-humus abrasems (disturbed brown soils) | Anthropogenically modified areas as a result of mineral exploration activities |
| Meadowed brown soils | Anthropogenically modified areas as a result of mineral exploration activities |

Sampling and testing of soils suggest that in accordance with the Russian standard, the vast majority of soils within the Project area can be used, based on their environmental characteristics, without limitation. There have been some contaminated soils identified through field surveys, notably in the area along the access road (near the mouth of the Sukhoi Log Creek). These contaminated soils are likely the result of geological and exploration works that have been conducted to date. Remediation plans for these contaminated soils that are currently known, and any found during the Project life, will need to be developed to outline measures such as testing, excavation, and either disposal to landfill locations, or blended/layers as part of site pad construction. The feasibility study does not include an allowance to remediate any historical impacts that may be caused to date by Project activities.

### *Plant Life*

The Project area is located in the mountains of the Verkhoyansk district of the Bering northern taiga sub-province of Cajander larch (Larix cajanderi) forests. Dominant types of plant associations are larch forests and woodlands, and mountain tundra. In valley complexes, chosenia woods and willow shrubs also occur.

Protected species identified within the Project area include five species of vascular plants and three fungi species listed in the Red Data Book of the Russian Federation and the Red Data Book of the Republic of Sakha. Four species were identified within 1,000 m of Project infrastructure that will require protection. There are also unique ecosystems to these areas that will also require protection. Several small steppe areas that are the relicts of the Late Plestocene occur only sporadically and are rare in the north-eastern part of Yakutia.

Valuable medicinal and food plants occurring within the Project area are cowberry, ledum, blueberry (*Vacinum uliginosum*), cranberry, dwarf pine (*Pinus pumila*). These

species are a wide-spread plant resource across the entire Yakutia taiga, and the due to the remote location, the potential for harvesting volumes in the Project area is low.

### *Animals*

The diversity of terrestrial vertebrates (wildlife) in the Project area is low due to climatic conditions and specific features of the mountain terrain. In addition, the Verkhoyansk Range, which extends from the Arctic Ocean to the Sea of Okhotsk coast, serves as a natural barrier for the migration of animals.

Important wildlife species in the Project area include Snow sheep, elk, Musk deer, and Reindeer that support economic livelihood for local residents and communities. Other wildlife in the area includes brown bear, gray wolf, wolverine, lynx, sable, stoat and the black-capped marmot. Primary game/fur animals hunted by the local population (i.e. reindeer herders) are squirrel and ermine and, in recent years, sable has been steadily becoming more popular as a game/fur animal. Birds noted in the area include willow ptarmigan, Eurasian sparrowhawk, merlin, common kestrel, golden eagle and Eurasian eagle-owl. The maximum diversity and specificity of wildlife species is observed in river valleys in the mountain forest belt. The lowest diversity is in the forest belt of mountain slopes, specifically in mountain tundra complex.

No amphibians or reptiles occur in the Project area.

The majority (50%) of the entomofauna species occur in meadow-type habitats with forests and meadow-forests providing habitats for 24% and 20% of insect species, respectively. The remaining 6% of species occur in mountain-tundra, tundra, bog, steppe, and meadow-steppe habitats.

Within the Project area and area of influence there are no species of mammals listed in the Red Data Book. However, the black-capped marmot (*Marmota camtschatica*, Pallas) are registered in adjacent area (N65°42,119 E129º59,219), (N65°43,465 E130º9,588) to the Project.

Two species of birds (golden eagle and eagle-owl) and three Lepidoptera species (*Parnassius tenedius* (Ev.), *Parnassius phoebus* (F.) and *Colias hecla viluensis* (Mén.) that are listed in the Red Data Book of the Russian Federation and the Red Data Book of the Republic of Sakha were identified within Project area. The closest nests are located within 1,000 m from Project facilities. Monitoring of these nests is recommended during Project construction and operation.

Key fish species occurring in watercourses of the Project area are grayling and burbot, both of which are not rare or protected and have no commercial fishing value. Local residents undertake recreational fishing for household consumption.

In accordance with the regulations of the Federal Agency of Fisheries, the rivers within the Project area fall under the following fishery categories:

- the Arkachan River can be classified as a water body of the highest fishery category due to the occurrence of *Coregonus lavaretus pidschian* and *Hucho taimen*

- the Endybal, Sirelendge and Fedor-Urege Rivers fall under the first fishery category as watercourses used for reproduction, wintering, and feeding of *Thymallus arcticus.*

According to Russian Federation regulatory requirements, the water quality of watercourses with fishery significance should be maintained at the same level, with no contaminants discharged without treatment, assuring the meeting of regulatory standards. As illustrated in Figure 20.1, these waterways already exceed the $MPC_f$; in particular there are elevated copper and zinc concentrations.

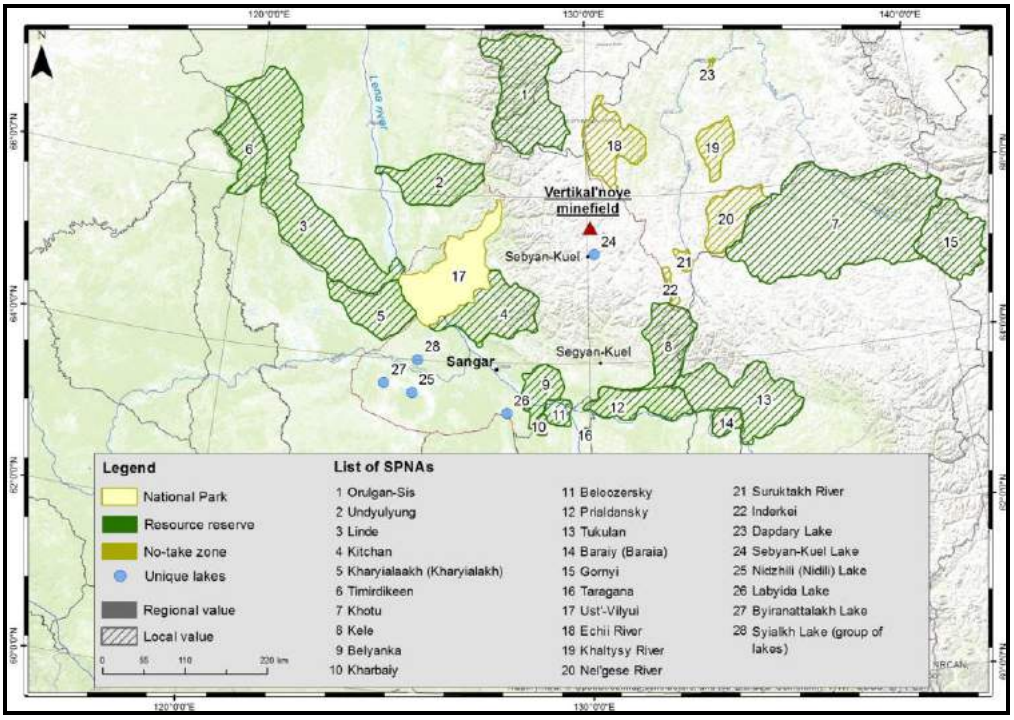
There are no Special Protected Natural Areas (SPNAs) in the Project area; however, more than 20 SPNAs of local and regional value have been established in the Kobyaysky Ulus and other surrounding uluses of the Republic of Sakha (Yakutia) (within a 200 km distance from the license area), including one national park, 16 resource reserves, 6 no-take zones, and 5 unique lakes. The nearest SPNAs to the Project are shown in Figure 20.6 and include:

- Echii River no-take zone with an area of 229,800 ha - of the local significance;
- Unique Lake Sebyan-Kyuyol with an area of 2 071 ha – of the regional significance.

No Ramsar territories (the Convention on Wetlands of International Importance, especially as Waterfowl Habitat) are located in the Project area of influence.

Key bird area “Forty islands” (RU3064) is included in the list of Important Bird and Biodiversity Areas (IBAs) developed by BirdLife International and located within the territory of SPNA natural park “Ust’-Vilyuysky”. It is included in “indirect list” of Ramsar wetlands as it provides habitat and nesting areas for approximately 20 rare bird species, including water fowls.

**Figure 20.6 SPNAs in the Surroundings of the Project Area**




## 20.3.3 EXISTING SOCIO-ECONOMIC CONDITIONS

Existing socio-economic conditions are provided based on the report on the results of socio-economic survey performed by ERM in 2015 (ERM 2015).

The Project area (Figure 20.7, license area) is located a considerable distance from both the Kobyaysky district (Ulus) center Sangar (approximately 330 km by roads or 200 km by air) and from the republic administrative center Yakutsk (approximately 400 km by roads).

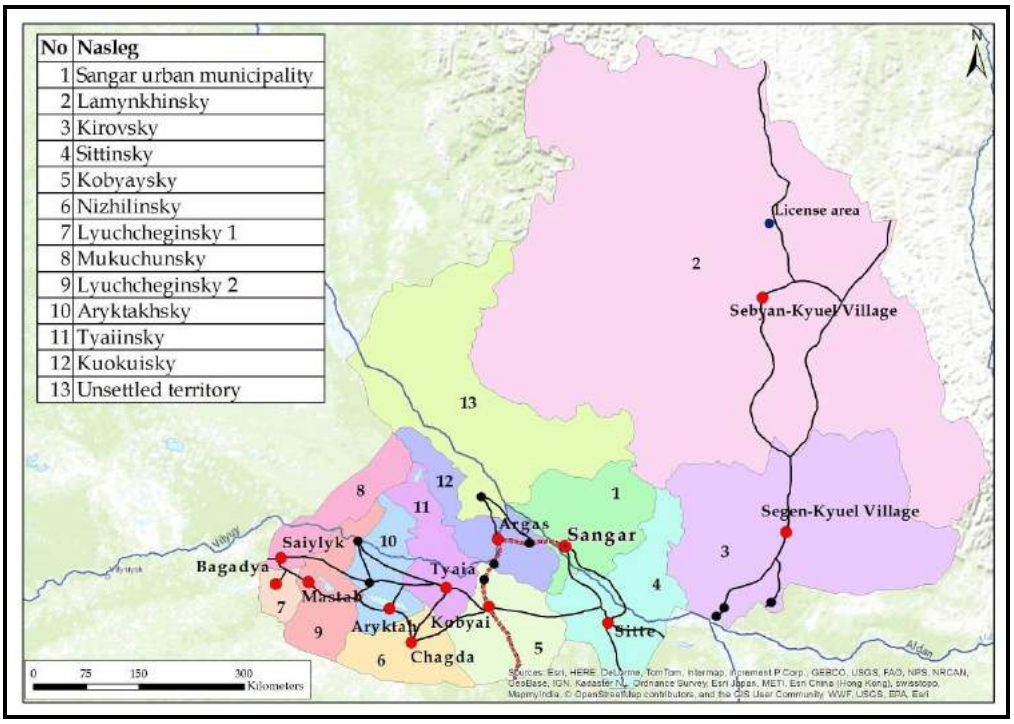
The Project Area is located in the Lamynkhinsky Nasleg ("Nasleg" is the lower level of the administrative territorial division of the Sakha Republic).

The Project area is a zone of residential area of indigenous peoples of the North of the Evens (the Evens) (Lamuts): 714 of 773 people of the Nasleg (92%).

The Evens are one of the indigenous peoples of the north living in vast north eastern territories of the Russian Federation. The Evens population of the Lamynkhinsky Nasleg is steadily increasing. Remoteness and restricted accessibility have preserved the traditional Evens culture within the Lamynkhinsky Nasleg.

Traditional Evens economy is reindeer herding, supplemented with fishing and hunting game for meat and fur. The Evens families are private owners of reindeer herded together with reindeer of State Unitary Enterprise (SUE) Sebyan. The Project footprint and the seasonal access road will intercept grazing areas traditionally used for reindeer herding. Silver Bear has initiated a process to assess and valuate compensation that will be provided to the affected herders. Negotiations are not complete.

**Figure 20.7 Location of License (Project) area in Kobyaysky District**




Reindeer husbandry in the Lamynkhinsky Nasleg also includes reindeer herders of SUE Sebyan. SUE Sebyan consists of several teams each using its own grazing/herding areas and camping sites; two teams (No. 5 and No. 9) have been using the Project area:

- Team No. 5 traditionally migrates in the area of the abandoned Village of Endybal. The team is comprised of six reindeer herders and three chum-keepers and grazes more than 1,000 reindeer, including 583 heads of SUE Sebyan and privately owned animals. Routes of late-autumn and early spring movements are located near the Endybal village and partly near the Project area. A fawning ground used by the team in April/May is located near the former settlement not far from the license area.
- Team No. 9 of SUE Sebyan migrate near the winter road of regional significance, Batamai to Sebyan-Kyuel. As of March 2015, the herd numbered 1,000 reindeer, including 500 privately owned animals. The team is comprised of six reindeer herders and three chum-keepers.

The Evens families have no legal title to land; however, grazing and herding areas of the SUE Sebyan are historic areas determined during the time of the former Soviet Union.

The Evens families of the Lamynkhinsky Nasleg preserve their traditional work as reindeer herders. The local school and community clubs make efforts to preserve the Evens language, national culture, folk songs and dances; however, the economic and social life of the Evens is currently undergoing a transformation as young villagers now rarely become reindeer herders, refusing to migrate with reindeer all-year round. Reindeer herding practices are also changing, which results in shorter migration routes, fewer campsites, and camp moving less often. The Evens are simultaneously

integrated into the Russian cultural space. All these external influences threaten the traditional Evens lifestyle.

The Association of the Indigenous Peoples of the Sakha Republic (under the presidency of Andrey V. Krivoshapkin, Sebyan-Kyuel Village) is the main public organization uniting indigenous communities in the region.

The Project area can be regarded as having a high potential in terms of the use of its ecosystem services by the local communities. The most extensively used ecosystem services are in areas around Sebyan-Kyuel, along the winter road, and reindeer herders' migration routes.

The most important ecosystem services are graze land resources extensively used by the local reindeer herders. Other important land use in the area are hunting and fishing resources as one of the main sources of household incomes, and an important food source for the local communities. Hunting is predominantly commercial, the sable being the main game animal. OJSC FPK Sakhabult (private commercial enterprise of agricultural and industrial specialization, specializes on hunting and processing of fur) holds a commercial game hunting license with a wildlife management area (WMA) of 1,835 ha within the Project area (17% of the total area of Ulus).

Fish caught in the local lakes and rivers are the second most important local source of food after reindeer meat. Residents of Sebyan-Kyuel mostly access fish on the lakes located east of the settlement. The locals also fish at the rivers, including the area near the former Endybal Village (the Arkachan River).

Timber resources are significant for the local communities as the majority of houses have stove heating. However, timber reserves are small in mountainous areas. Mature forests around settlements have essentially been cleared.

Wild berries (bog whortleberry, cranberry, cowberry, currants, etc.), mushrooms (orange-cap boletus, orange agaric, yellow boletus, etc.) and medicinal herbs are gathered around the village primarily for personal consumption.

According to official information, no cultural heritage sites (of federal, republic, or local (municipal) significance) listed in the Russian National Uniform State Register of Cultural Heritage Sites or identified cultural heritage sites are located within the Project area. An archaeological survey was completed as part of the ethnological assessment during the summer of 2015. The survey confirmed an absence of any objects of cultural heritage within the Project site.

Some sites of spiritual and religious value for the local community are located near Sebyan-Kyuel and the Project site. A shaman's grave (northwest of the Project) and ancestral burial sites (in the former Endybal Village) are located 10 to 15 km from the Project. Some sites of worship (shaman's grave, ancestral graves, sacred trees) are located near the winter road and include these ancestral burial sites worshipped by individual families and the Evens worship graves of shamans and sacred natural sites.

### 20.3.4 STAKEHOLDER AGREEMENT

Major stakeholder groups connected with the Project were identified during the scoping stage of the Project. Table 20.5 includes the key groups of external and internal stakeholders.

Activities undertaken as of June 2016 by Silver Bear and its consultants have included public hearings in line with requirements of the RF regulations and informal consultations with local communities and authorities during the data collection in the course of the socio-economic study.

Key interests and concerns identified by ERM that have been raised to date through the stakeholder engagement include:

- employment opportunities for young people from the village of Sebyan-Kuel that would reduce the outflow of young people in other settlements of Yakutia
- negative impact on traditional activities of the community of Sebyan-Kuel, mainly related to reindeer herding
- overall effect to the health of reindeer herders, and the residents of Sebyan-Kuel.

ERM helped Silver Bear establish formal stakeholder engagement procedures, including the development of internal and external grievance mechanisms.

Prognoz signed an agreement for social and economic cooperation with administration of the Nasleg (municipality) and the Ulus (district) in March 2013. The agreements are aimed to cover the relationship between Silver Bear and local administrations in the course of the exploration activities. According to Silver Bear, framework agreements to cover construction and operation terms are concluded with administrations of all levels (republic, ulus(district) and nasleg (municipality). The size and/or form of financial and other assistances to local communities, the communication channels, tools of support distribution etc. shall be defined on the basis of annual consultations with relevant authorities.

**Table 20.5 Key Project Stakeholder Groups**

| Group | Stakeholders |
|---|---|
| Indigenous people (Evens) | • Indigenous people whose reindeer herding camps and routes are located close to the Project site |
| Residents of the settlements located near the Site and associated infrastructure facilities | • Residents of Sebyan-Koel, Segen-Koel and Batamay settlements |
| Organizations and individuals whose property rights will be affected by temporary or permanent withdrawal of land plots during the Project implementation | • Enterprises of the Lamynkhinsky nasleg, that are located close to the Project site (mainly commercial hunting and herding groups, Sakha-bult and SUE Sebyan) |

*table continues...*

| Group | Stakeholders |
|---|---|
| Government authorities and regulators | • Federal authorities<br>• Sakha Republic regional authorities;<br>• Local authorities (administrations of the Kobaysky ulus, Lamynkhisky and Kirovsky naslegs) |
| Non-government organizations, independent experts | • Specialized environmental, public and research organizations, experts (Association of the Indigenous people of Sakha republic, etc.)<br>• Public organizations promoting social programs<br>• Other public organizations in the Project area |
| Beneficiaries of Silver Bear's social programs | • Communities of Sebyan-Koel, Segen-Koel and Batamay settlements |
| Mass media | • Local and regional internet recourses:<br>• Newspaper "Yakutiya"<br>• Local and regional internet recourses:<br>– www.ysia.ru<br>– www.sakhalife.ru<br>– www.gold.prime-tass.ru<br>– www.vedomosti.ru |
| Personnel of Silver Bear, Organizations involved into the Project implementation and subcontractors | • Construction and project organizations involved into the Project implementation<br>• Company's personnel and subcontractors' employees<br>• Consultants involved into the Project implementation |
| Organizations involved into personnel training and selection | • Educational institutions on basis whereof training of personnel for the enterprise is realized<br>• Recruitment centers |

## 20.4 Environmental and Social Impact Assessment, Mitigation and Management Plans

### 20.4.1 Environmental and Social Impact Assessment

Consideration of environmental and social factors throughout the entire lifecycle of the Project (preparatory works, construction operations, production operations, and decommissioning) is an essential prerequisite to successful projects.

In order to meet both Russian and international requirements, Silver Bear prepared at the time of this report the following as part of the impact assessment process (as described in Section 20.1.2):

- As required by Russian regulatory requirements, and based on a range of studies and surveys as listed in Table 20.1, Silver Bear developed Russian design documentation including materials for an ESIA and an environmental protection plan (EPP). Silver Bear completed development of part of the Russian design documentation, including materials for an ESIA and EPP covering the mining and waste management sections and submitted it to the

authorities for review as part of the regulatory approval process. Russian design documentation for the processing plant is under development and was not provided to ERM for review. The State Environmental Review has been completed and approval granted in October 2016. Silver Bear will need to confirm with the relevant authorities whether an amendment to this approval is required as a result of Project changes reflected in the updated FS.

- In accordance with international requirements Silver Bear has developed international Environmental and Social Impact Assessment (ESIA) based on Feasibility Study as originally released. The ESIA was completed by ERM on behalf of Silver Bear in July 2016. The Environmental and Social Management Plan (including specific MPs) to address the impact and issues identified by the ESIA were developed by ERM in August 2016. However it is recommended to perform the Gap Analysis of Silver Bear's performance against the IFC Performance standards based on recent Project's updates and to develop an Environmental and Social Action Plan which will include steps to cover the gaps identified.

Developing two sets of documents in accordance with Russian and international requirements is a common practice for Russian projects due to the different format and level of detail required by the Russian regulations, as compared to international community.

As the ESIA has not yet been completed as of the date of this report, the assessment of potential effects of the Project, the development of mitigating and management measures, and the establishment of monitoring programs embedded in the feasibility study are preliminary and expected to evolve over time. The results of ongoing work, including ongoing environmental studies, stakeholder engagement, and permitting have the potential to influence the design, operations, and economic results of the Project. In not having completed the ESIA, there is a risk that there the Project may cause environmental and social impacts that could otherwise have been avoided. This risk is amplified given that construction activities are already underway.

The State Environmental Review was completed and approved after the effective date of the FS. As such, the FS does not consider the impact any terms and conditions associated with this approval may have on the Project and its design. ERM has not completed a gap assessment of the FS Project and the requirements associated with the State Environmental Review.

### 20.4.2 Environmental and Social Management Plan

Table 20.6 presents a summary of key identified environmental and socio-economic aspects of the local area and proposed mitigation measures and management controls that have been considered in Project design and planning. Given that the project design development and construction activities are ongoing, there may also be additional mitigation and management measures under consideration to further reduce the negative effects during construction and operation, and to meet closure objectives. The State Environmental Review may have included terms and conditions related to mitigation and control measures not contemplated by the Project. There is the potential for additional measures to be material to the Project.

**Table 20.6 Environmental and Social Potential Impacts and Proposed Embedded Design Mitigation**

| Aspect | Risk/Potential Impact | Mitigation & Control Measures |
|---|---|---|
| Geology | • ARD/ML from newly exposed rock surfaces, rock used for infrastructure construction, surface storage of waste rock and/or processed ore tailings, resulting in impacts to surface water sources; and<br>• Mobilization of fine particles by wind or water, potentially leading to increased amounts of dust in the air or deposition to area land and water. | • Preliminary studies indicate that the waste rock and tailings generated by the Project will be NAG but will likely leach elevated concentrations of metals including zinc, lead, cadmium, silver, and arsenic and antimony. These parameters are also elevated in the existing surface water environment.<br>• Roads and pads used for infrastructure development will use surface and/or quarry rock designated as low risk for ARD/ML.<br>• Waste rock will be stored on surface in a dedicated facility. Seepage from the waste rock will be combined with contact water from the site and directed to an unlined exfiltration pond to remove suspended solids. Water quality will be monitored to confirm compliance with regulatory requirements for release to the environment.<br>• Tailings will be stored on surface as a filtered dry stack. The facility will be lined and during operations any excess water will be pumped from a clarification pond and directed to the process plant for recycling. The TMF will operate as a zero discharge facility during normal operations.<br>• Further testing of materials will be required to validate initial conclusions regarding the potential for ARD/ML. The feasibility study assumes that beyond the use of an exfiltration pond, downgradient of the WRD water treatment will not be required to protect the environment and meet regulatory requirements. Further work is required to validate this assumption. |
| Ground Stability and Permafrost | • Siting and/or design of facilities results in permafrost degradation, ground stability, or other alterations of the active or inactive soil layers resulting in facility failures and impacts to the receiving environment. | • A siting trade-off study was completed by SRK (Appendix K) and geotechnical conditions were considered as part of this study. The TMF and WRD are located in areas covered with shallow, generally-granular overburden, over sedimentary bedrock. The feasibility study concluded that the risk of soil subgrade instability is low. |

*table continues...*

| Aspect | Risk/Potential Impact | Mitigation & Control Measures |
|---|---|---|
| Groundwater | • Impacts to groundwater regime due to the use of water for mining and milling purposes. | • A water sourcing study was completed by SRK (Appendix K others and concluded that sufficient groundwater is available to support Project demands. Drawdown of the deep aquifer is not expected to result in unacceptable impacts to the natural environment and there are no other users of this water. Mining occurs within the zone of permafrost and is not expected to have a material impact the groundwater regime. |
| Surface Water Quality | • Impacts to the water quality in the Sirelendge River and/or its tributaries due to the physical disturbance to river sediments, discharge of treated sewage, seepage of water with elevated TSS and/or metals from the exfiltration pond downgradient of the WRD and runoff from project infrastructure, including the access road between the camp and the mine (which will cross the creek) and the access road from the airstrip to the Project site (which is aligned to the river bed). Deposition of dust to water bodies from use of roads and from the dry stack TMF.<br>• Spills to surface water bodies from hydrocarbon storage and transport. | • The general site arrangement for the Project site was designed to protect surface water quality by directing contact water through a series of runoff collection ditches to a seepage and runoff collection pond adjacent to the northeast boundary of the WRD. This pond will act as a sediment control pond allowing sediment to settle out prior to release of excess water to the receiving environment. Sewage from the camp site will be treated and trucked to the TMF. Monitoring of site discharges and of the receiving environment will be undertaken to confirm the effectiveness of controls.<br>• The feasibility study assumes that water content and weather conditions will suppress dust from the TMF. This assumption will be validated through site monitoring and further mitigation, including the use of dust suppressants, if necessary.<br>• Monitoring of direct and indirect impacts (water quality, biota, fish and fish habitat) from vehicular travel along (and within) the river valley and river channel between the airstrip and the camp, and the camp and the mine site will be undertaken. Consideration should be given to the relocation of the airstrip to the other side of the river in order to reduce the potential impacts to the river. Relocation of the airstrip is not included in the feasibility study.<br>• Standard operating procedures, such as restricting travel to authorized areas, speed control, and road watering to control dust. Hydrocarbon storage facilities designed with secondary lining and the establishment of spill response plans. |

*table continues...*

| Aspect | Risk/Potential Impact | Mitigation & Control Measures |
|---|---|---|
| Hydrology | • Disruption of the natural flow patterns of surface runoff to Sirelendge River and its tributaries due to the Project footprint resulting in a loss of drainage and potential impacts to the aquatic environment.<br>• Impacts to the surface water environment due to loss of water to the open pit or underground mine workings. | • Compact project footprint located at the headwaters of the drainage basins for the Porfirovy Creek and the Borisovsky Creek. The main project infrastructure intersects approximately 13% and 4%, respectively, of the total catchment area for these tributaries and 0.51% for the Sirelendge River.<br>• Potential reduction in flows considered minor. Hydrological monitoring should be conducted during operations to confirm the impacts to the aquatic environment are not occurring.<br>• Mining is contained entirely within the zone of continuous permafrost. All zones of mining are above the invert elevations of the local creeks and the Sirelendge River. Excess contact water that collects in the pit and underground workings (precipitation and drill water) will be collected in sumps and pumped to the exfiltration pond adjacent to the WRD. |
| Aquatic Life (including fish and fish habitat) | • Project activities directly removing or altering fish habitat (e.g. culvert installations and reduction in stream flows below normal low levels).<br>• Project activities potentially affecting water quality or sediment quality. | • No direct impacts to fish and fish habitat are expected as a result of Project infrastructure. Any discharges to the receiving environment will meet regulatory discharge criteria and the receiving environment will be monitored.<br>• Road travel between the existing airstrip and the camp site generally follows the shoreline of the Sirelendge River and must be crossed as the airstrip and camp are on opposite sides of the river. An allowance has been made in the feasibility study for an engineered crossing and the road and crossing should be included in the project design documentation. The Sirelendge River is a sensitive fish habitat and an engineered crossing will reduce potential impacts through the use of culverts. Monitoring of direct and indirect impacts (water quality, biota, fish and fish habitat) from vehicular travel along (and within) the river valley and river channel between the airstrip and the camp, and the camp and the mine site, will be undertaken. Consideration should be given to the relocation of the airstrip to the other side of the river in order to reduce the potential impacts to the river.<br>• Standard operating procedures, such as restricting travel to authorized areas, the implementation of spill response plans, and the use of dust control will prevent direct and indirect impacts to fish and fish habitat. |

| Aspect | Risk/Potential Impact | Mitigation & Control Measures |
|---|---|---|
| Terrestrial Ecosystem | • Loss of ecosystems and vegetation to footprint of Project and supporting infrastructure.<br>• Degradation of ecosystems and vegetation through increased dust deposition, potential introduction of invasive plants, alteration of local hydrology, and effects caused by chemical spills. | • Compact project footprint that directly impacts approximately 637 ha of terrestrial habitat. Use of a seasonal road for resupply purposes to reduce impacts to the terrestrial environment, protected plant species identified in the Project area will require special measures that may include protection zones, replanting programs and education and awareness programs. There are also unique ecosystems to the area that will need similar special measures.<br>• Standard operating procedures, such as restricting travel to authorized areas, dust control, spill response planning, and vehicle washing will reduce operational level impacts to the terrestrial environment. |
| Terrestrial Wildlife | • Habitat loss (direct and indirect).<br>• Changes in movements and/or behaviors.<br>• Mortality (direct and indirect).<br>• Attraction of animals to human use sites. | • Compact project footprint that directly impacts approximately 637 ha of terrestrial habitat. Use of a seasonal road for resupply purposes to reduce impacts to the terrestrial environment.<br>• Loss of grazing and migration areas for reindeer will be offset through a compensation agreement with affected herders.<br>• Standard operating procedures, such as restricting travel to authorized areas, restricted speed limits on travel, avoiding nesting areas, and effective domestic waste management will reduce operational level impacts to local wildlife. |
| Air Quality and Noise | • Airborne particulates<br>• Sulphur dioxide;<br>• Nitrogen oxide;<br>• Fugitive dust<br>• VOCs<br>• GHGs<br>• Diesel engine exhaust from vehicles. | • Increased dust emissions (with elevated lead and arsenic) due to drilling, mining, processing activities (loading, crushing, grinding) and road traffic are the primary sources of air emissions. Installation of dust control and collection systems (e.g. reagent mixing, grinding) in the processing plant and standard operating procedures, such as restricting travel to authorized areas, speed control, and road watering to control dust along roadways. Use of modern equipment and standard operating procedures for the efficient use of fuel will minimize emissions such as mono-nitrogen oxides. Equipment designed to Russian design standards to reduce noise to acceptable levels. |
| Climate | • Release of GHGs. | • Use of modern equipment and standard operating procedures for the efficient use of fuel. |

*table continues...*

| Aspect | Risk/Potential Impact | Mitigation & Control Measures |
|---|---|---|
| Socio-Economic and Land Use of Indigenous People Communities | • Employment and income opportunities, as well as other issues.<br>• Education, training, and skills development opportunities.<br>• Business opportunities and economic development.<br>• Indigenous community stability and well-being impacts.<br>• Loss of livelihoods and income of indigenous people due to loss of reindeer grazing areas. | • Establishment of socio-economic management plan that includes the following measures:<br>– project recruitment, employment and training plan to maximize local employment<br>– cooperation programs with central and local educational institutions; on-the-job training programs<br>– local content and procurement plan to maximize business and economic opportunities<br>– livelihoods restoration plan including establishment and distribution of a compensation fund to offset the Project impact and regular communications with the local herders and indigenous communities<br>– community development program. |

Note: TSS – total suspended solids; VOG – volatile organic compound; GHG – greenhouse gas

## 20.5 WATER AND WASTE MANAGEMENT

This section briefly describes the interaction of the Project with the environment during the operations phase, as it specifically relates to the management of water and wastes based on the current design of the facilities described in other sections of the feasibility study.

### 20.5.1 WATER MANAGEMENT

#### *WATER SUPPLY*

Water supply (Section 18.12) will be provided from a groundwater well located in the Sirelendge River valley next to the camp. From a storage tank at the pump station, the raw water supply will be pumped via a 4.5-km pipeline to the raw water tank located at the processing facility. The pipe line between the pump station and the mill will be routed up the Borisovsky Valley and along the ridge to the west of the road. There are no any other users of ground water in the area and work completed by NSI (2016) has concluded that no material environmental impacts are expected from the use of this water.

During construction, water supply will be extracted from the Sirelendge River and trucked to the camp and process plant until the pump station and pipeline are available to provide the water supply.

#### *SITE CONTACT WATER*

The general site arrangement for the Project has been designed to protect surface water quality by directing contact water through a series of runoff collection ditches to a seepage and runoff collection pond adjacent to the northeast boundary of the WRD.

This pond will act as a sediment control pond allowing sediment to settle out prior to release of excess water to the receiving environment (Borisovsky Creek).

Contact water in the open pit and underground mine workings is anticipated to be limited to drill waste water and precipitation, as these operations are within continuous permafrost conditions and no groundwater inflow is expected. This contact water will collect in sumps for reuse in drilling if feasible, or pumped to the seepage and runoff collection pond adjacent to the WRD.

The current water balance developed for the Project should be expanded to include site-wide surface water sources, including contact water that collects in the seepage pond, water from the TMF, and open pit and underground mine water. This water balance should be developed to characterize both the quality and quantity of water that will be managed site wide. The current model was not used to predict water quality. The water balance should be used in conjunction with a site-wide water monitoring program to validate model predictions and confirm that environmental mitigation measures are effective and discharge can occur in accordance with anticipated permit conditions without further treatment.

### 20.5.2 Tailings and Waste Management

#### *Solid Waste and Sewage*

As outlined in Section 18.13, solid waste will be stored in the solid waste storage facility, located to the west of the processing plant. The solid waste storage facility will be lined and segregated to handle different waste streams.

A sewage treatment plant will be located at the camp to accommodate the camp and sewage trucked from the processing plant washroom facilities. Treated waste water will be trucked to the TMF and the solid sludge from the sewage treatment plant will be trucked to the TMF and stored with the tails.

#### *Geochemistry of Waste Rock and Tailings*

To date, the preliminary characterization of the waste bedrock and saprolite has been undertaken by ERM on a limited number of samples and incorporates testing to classify solid material based on parameters that leach from the material (ERM 2016b).

Static acid-base accounting methods indicate that the NP is in excess of the acid AGP due to the elevated carbonate and low-sulphur content for most of the waste rock and tailings. In accordance with the assessment of AGP and geochemical characteristics of waste rocks, the elements with high concentrations in waste rock are zinc, lead, cadmium, silver, arsenic, and antimony. A wide range of elements characterized by high concentrations were found in aqueous extractions that simulate expected waste rock drainage. Concentrations of the following elements may potentially exceed the MPC established under Russian law: sulphate ion, magnesium, iron, aluminium, zinc, selenium, thallium (1.1 to 13.0 MPC), manganese, cadmium (1.1 to 140.0 MPC). However, the levels appear to be generally within the hydro-chemical background levels found in the Project area. Acceptable water quality for discharge will be further confirmed with the authorities when Silver Bear applies for

the discharge permit. The feasibility study does not include an allowance for active treatment of seepage waters from the waste rock or tailings waste.

It is recommended to conduct further ARD/ML studies in order to align sampling with final mine layout and to get statistically reliable results.

Consideration of this potential for ARD/ML has been considered in Sections 18.10 and 18.11.

#### *Waste Rock Dump and Overburden Stockpiles*

The open pit will have a dedicated WRD and overburden stockpile during construction and operation. The waste material will consist of waste bedrock and waste saprolite. Details on the design of these stockpiles, including the associated peripheral and internal drainage systems are provided in Section 18.11.

#### *Tailings*

The whole tailings generated in the process plant will be discharged into the TMF. The TMF will be constructed 0.2 km northeast of the process complex and will cover an area of 7.69 ha, storing approximately 0.8 Mt of dry (85% w/w) tailings material over the 7.4-year LOM. The dry waste storage area will consist of a HDPE lined pad surrounded by a rock fill perimeter berm. There will be a clarification pond at the eastern toe of the TMF waste stack with associated perimeter containment dam.

During construction and operation phases, and under normal conditions, the TMF will be a zero discharge facility. Seepage will be diverted to the process plant after the clarification pond. Details on the TMF design, including the schedule for dam construction are provided in Section 18.10. This design results in a low risk to the receiving surface water environment during normal operations.

## 20.6 ERM Comments

The feasibility study update for the Project is based on a revised mine plan to reflect the results of a more recent drilling program conducted at the property. ERM has updated its summary of the environmental, social, and regulatory factors on an assumption that no material changes regarding the interaction between the Project and the natural and social environments are introduced with the revised mine plan. As such, the original review of environmental and social factors completed by ERM is considered to remain accurate.

For the purposes of the update, ERM has summarized the current status of the regulatory factors for the Project based on information regarding permitting provided by Silver Bear. Review of permitting details, including the potential implications of terms and conditions in any permits received by Silver Bear and/or commitments made in updated regulatory applications has not been conducted by ERM. ERM has considered the status of permitting provided by Silver Bear to be accurate. ERM is not the author of Section 20.6 on Mine Closure and Reclamation.

ERM provides the following overarching comments and recommendations.

- Project documentation required for the Russian regulatory review and approval process is currently under development, and has been developed in parallel with completion of the feasibility study and an ESIA. The assessment of potential effects of the Project, the development of mitigating and management measures, and the establishment of monitoring programs embedded in the feasibility study are considered to be preliminary and are expected to evolve over time. The results of ongoing work, including ongoing environmental studies, stakeholder engagement, and permitting have the potential to influence the design, operations, and economic results of the Project.
- The Project is in the early stages of the Russian review and approval process. As part of this process, the environmental and social aspects of Project are being evaluated by the regulatory authorities. There can be no guarantees that the Project will be approved under Russian law, the timeline for any decision, and if the Project is approved, that there won't be terms and conditions that have a material impact on the feasibility of the Project. ERM recommends that Silver Bear continue to actively engage with government authorities and community stakeholders as part of this process.
- ERM notes that the Project execution plan and schedule has been de-coupled from permitting activities. Construction activities are being undertaken without the necessary permits in place. Further, the commencement of mining is planned for Q4 2016 and ore processing in Q12 2017, whereas there is a high risk based on the current status that permits will also not be in place to support these operating stage activities by the dates assumed in the FS. In addition to real or perceived risks to safety and/or the environment, conducting these current and future activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material. ERM recommends that a detailed compliance assessment be undertaken and that Silver Bear work with regulatory authorities to address current and potential permitting/compliance gaps.
- The State Environmental Review was completed and approved after the effective date of the updated FS. As such, the FS does not consider the impact any terms and conditions associated with this approval may have on the Project and its design. ERM has not completed a gap assessment of the FS Project and the requirements associated with the State Environmental Review.
- The State Environmental Review was completed prior to the updated FS based on an optimized mine plan. ERM recommends that Silver Bear confirm with the regulatory authorities if an amendment to the approval is required.
- Project level socio-economic framework agreements have been negotiated with local stakeholders to mitigate potential socio-economic impacts of the Project. Cost estimation of social investments will be defined on the basis of annual consultations with authorities... ERM has not reviewed any cost allowances associated with these agreements that may have been included in the financial analysis of the Project presented in Section 21.

- Silver Bear has expressed its intention to comply with the Equator Principles and the IFC Performance Standards. A gap assessment against these international frameworks was completed for Silver Bear in November 2014 by ERM. ERM recommends that Silver Bear continue efforts to align the Project with these international frameworks as a means to inform project design and the development and implementation of project specific environmental and social management and monitoring plans. An updated gap assessment is recommended to assess the current level of alignment of the Project as defined by the feasibility study. The more advanced the Project the more difficult it may become to fill gaps remaining.
- Further engagement with local indigenous communities with regard to land and resources restoration is recommended to ensure that social requirements of the IFC Performance Standards are met.
- Further environmental studies are recommended to enhance the dataset characterizing the aquatic environment and confirm the source of elevated metals found in the local and regional waterways, including the potential impact of exploration and development activities that have already taken place. These studies should be used to inform the permitting process and to validate the effectiveness of environmental controls planned to protect the receiving environment.
- Vehicular travel adjacent to, and within the bed of, the Sirelendge River and its tributaries can present a risk to water quality and fish and fish habitat and is not in accordance with good international practice for environmental protection. The current plans also present a permitting risk with Russian authorities. ERM recommends Silver Bear undertake a trade-off study and evaluate the potential for relocation of the airstrip and re-alignment of the connecting road network. The project design documentation should be updated to include upgrades to this road and the airstrip as per Russian legislative requirements.
- The current water balance developed for the Project should be expanded to include site-wide surface water sources, including contact water that collects in the seepage pond, water from the TMF, and open pit and underground mine water. This water balance should be developed to characterize both the quality and quantity of water that will be managed site wide. The current model was not used to predict water quality. The water balance should be used in conjunction with a site-wide water monitoring program to validate model predictions and confirm that environmental mitigation measures are effective and discharge can occur in accordance with anticipated permit conditions without further treatment.
- During normal operations, the TMF will operate as a zero discharge facility; however, further study should be undertaken to define the conditions under which discharge to the environment is possible to assess the acceptability of this discharge. Further characterization of the tailings material and the potential for ARD/ML is required. The ARD/ML work completed to date is preliminary.
- A seepage and surface runoff collection pond will be constructed down gradient of the WRD that will act as a sediment control pond allowing settling of suspended solids prior to releasing water to be released to the

environment. Further study is recommended to characterize the predicted quality and quantity of this waste water to confirm the assumed acceptability of release without additional management or treatment. This study should include further characterization of the waste rock that will be generated by the project and confirm that no further mitigation is required to protect the environment during operations and closure phases. The feasibility study does not currently include an allowance for further treatment of seepage that is released from this pond.

- The establishment of more detailed management and monitoring programs will need to be designed and implemented to support construction, operations, and closure phases of the project. Current plans are conceptual in nature. Potential costs associated with the implementation of these programs have been included as an allowance as part of the G&A costs presented in Section 21. ERM has not evaluated these costs and has not commented on their adequacy.
- The existing planning for closure and reclamation (as presented by others) is currently at a conceptual stage. Further planning and costing is required to support future stages of the Project and validate the assumptions made in the study. Emphasis should be placed on defining the required technical studies needed to inform the evolution of the closure and reclamation plan over the life of the Project such that the end goals are met. Particular attention should be placed on infrastructure decommissioning, the closure of waste facilities and the management of water post-closure, including the potential need for water treatment.

## 20.7 CLOSURE AND RECLAMATION

Plans for closure and reclamation are addressed by discipline, in other sections of the report.

# 21.0 CAPITAL AND OPERATING COST ESTIMATES

## 21.1 CAPITAL COSTS

### 21.1.1 SUMMARY

The total estimated initial capital cost for the design, construction, installation, and commissioning of all facilities and equipment is $49,9 million. A summary breakdown of the capital cost is provided in Table 21.1 and further capital cost details are provided in Appendix I.

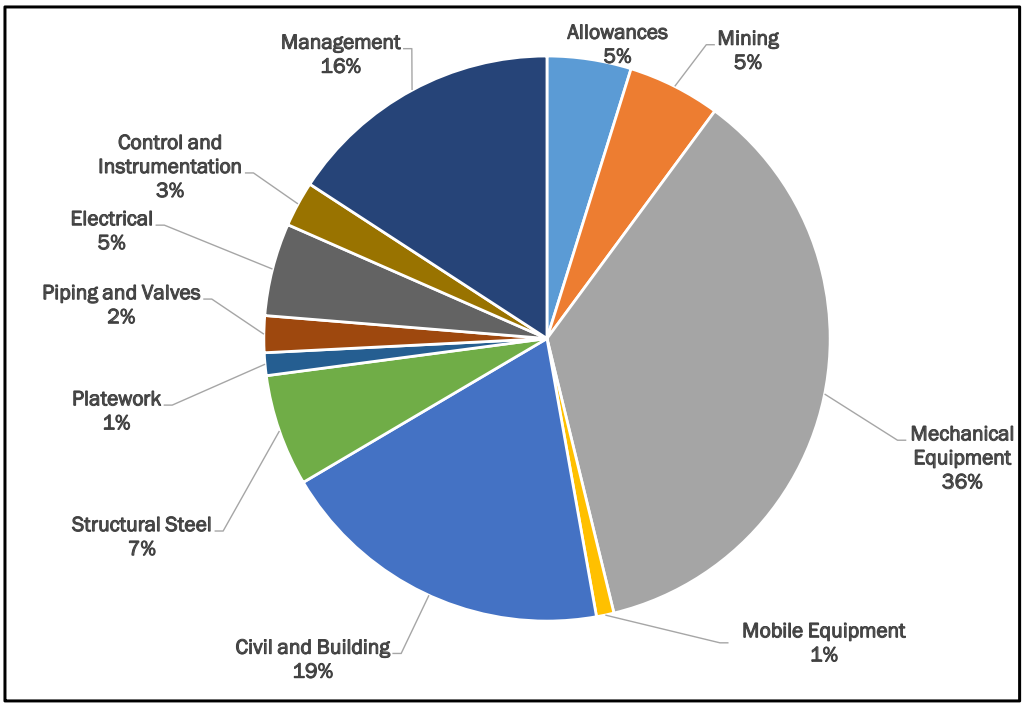
**Table 21.1 Capital Cost Summary**

| Area | Initial ($) | Sustaining ($) | Total ($) |
|---|---|---|---|
| Mining | 2,657,838 | 12,311,588 | 14,969,426 |
| Processing | 14,344,727 | 700,000 | 15,044,727 |
| Infrastructure | 3,717,106 | - | 3,717,106 |
| Utilities | 1,639,171 | - | 1,639,171 |
| TMF | 1,104,096 | 1,325,776 | 2,429,171 |
| Site Facilities | 5,360,289 | - | 5,360,289 |
| Off-site Facilities | 101,454 | - | 101,454 |
| Project Indirects | 11,194,311 | 70,867 | 11,265,178 |
| EPCM | 3,525,492 | 20,248 | 3,545,740 |
| Owner's Cost | 3,850,690 | 100,000 | 3,950,690 |
| Allowances | 2,374,759 | 831,232 | 3,205,991 |
| **Total** | **49,869,933** | **15,359,711** | **65,229,644** |

This estimate includes direct field costs required to execute the Project, plus indirect costs associated with design, construction and commissioning. This estimate is based on pricing as of Q3 2015, with no allowances for inflation or escalation. Elements of actual expenditures have been included, which further reduce the exposure to inflation or escalation. All currencies in this capital cost estimate is expressed in US dollars, unless otherwise noted.

Figure 21.1 illustrated an alternative view of costs per discipline showing the relational costs for the main packages required to establish the mine.

**Figure 21.1 Cost Percentages per Discipline**




## 21.1.2 Basis of Estimate

### *Class of Estimate*

This estimate is a Class 3 Estimate prepared in accordance with the AACE International (AACE) Cost Estimate Classification System. The estimate accuracy interval is -10% to +15%.

### *Estimate Base Date and Validity Period*

This estimate was initially prepared with a base date of Q3 2015. The quotes used in this feasibility study estimate were obtained in Q3 2015 and have a validity period ranging between 30 to 90 days.

Approximately two-thirds of the initial project capital estimate was committed by the time the estimate was updated, and thus the combined effect of highly competitive pricing by suppliers due to the current economic challenges and level of orders already placed for fixed amounts makes the further potential impact of cost escalation low.

### *Responsibility Matrix*

The Project estimate was produced by Tetra Tech as the lead consultant. The capital cost estimate was developed by a team of engineers, procurement specialists, and cost estimators with inputs from the client, which are presented by company and area of responsibility in Table 21.2.

**Table 21.2 Estimate Responsibility Matrix**

| Area | Company |
|---|---|
| Mining (open pit) | Tetra Tech |
| Mining (underground) | Tetra Tech |
| Processing | Tetra Tech |
| Infrastructure | Tetra Tech |
| Site Facilities | Tetra Tech (with input from Silver Bear) |
| Indirect Costs | Tetra Tech (with input from Silver Bear) |
| Owner's Costs | Silver Bear |
| Allowances | Tetra Tech |

### *Estimate Approach*

The main allocation of the estimate is the three-tier work breakdown structure, named Area, System and Estimate. Other allocations such as discipline are used as well to assist understanding, analysis and abstraction of information from the estimate. Reporting is done primarily to the work breakdown structure (WBS).

Prices and costs were determined based on international construction knowledge, combined with input from Prognoz obtained from contractors with local knowledge of climate conditions and government restrictions.

The estimate is primarily based on package costs, and client owned and sub-contractor team costs. Quantities not included in package supply, specifically civil and structural elements were estimated separately.

### *Equipment*

Generally, for major equipment, three or more suppliers were approached to provide a budget quotation. The vendors, selected from a Tetra Tech-approved vendor's list, were asked to provide equipment price, spares costs, delivery lead times, and freight costs to a designated marshalling yard for each major equipment package. Long lead item procurement overlapped with the feasibility study activities and where available, the firm equipment prices were used; significantly improving the estimate accuracy in these areas. A few major items were excluded from the standard procurement approach:

- Mining fleet: Silver Bear expressed a preference for Caterpillar as the supplier of the main mining fleet and only their prices were considered.
- Electrowinning process: this is a crucial part of the plant and was negotiated with Electrometals Canada Inc. who are specialists in this type of plant, and assisted the planning and design process.
- General allowances: no design or other indicative detail is available.

Other items in the capital cost estimate are based on the following information:

- Tetra Tech's in-house database for non-major equipment (i.e. equipment less than $50,000) or quotes from similar recent projects
- material take-offs (MTOs)
- all equipment and material costs are included as Free Carrier (FCA) manufacturer plant Incoterms 2010; other costs, such as spares, taxes, duties, freight and packaging, are covered in the indirect costs section of the estimate
- actual amounts of orders already placed, where available.

The small scale of the operation combined with a need to keep capital cost low and the site activities compact has meant that Silver Bear can use an owner-managed team to complete general earthworks and road construction. As a result the earthmoving costs were calculated taking into account the use of available materials on site and a team of directly employed personnel forming a fixed monthly cost during the construction period.

It is assumed that ramps and haul roads will be constructed from materials generated during mining activities and that the cost outside mining and discard, which is included in the mining costs, will be limited to some shaping, levelling, and compacting activities only. Unit rates were calculated from database rates, but with the aforementioned low effort for a fit-for-purpose approach taken into account.

#### *Concrete*

The cost for concrete works is mainly contained in materials purchased, labour expended, and projections to completion. Where applicable for work planned forward, the rate of RUB15 600 ($236,36)/m$^3$ was applied for the material (cement, reinforcement steel and formwork) portion with the labour produced under the team allowance. Aggregates will be supplied on site and the limited costs for preparation thereof included in general site costs.

#### *Structural Steel*

The structural steel elements are mostly in design/build packages for which the best available package costs were included. For secondary support and access, steel quantities were assessed based on experience of similar plants.

The base rate of RUB69 000 ($1,045,45)/t for steel and RUB85 000/t for platework supply derives from local quotations as well as the approach of the labour executed by Owner's team and not related to the costs of a major structural steel, mechanical, plate and piping contractor.

Adjustments were made to include the impact of actual costs where available.

#### *Electrical, and Control and Instrumentation Installation*

The cost for electrical infrastructure and distribution consists of the following main elements:

- power generation, for which quotations for containerised generation units were considered

- switchrooms (facilities and switchgear), for which preliminary quotations were compared with experience of costs for similar installation and provisions allowed accordingly
- power distribution, which is localised as power generation units will be placed local to different main areas,

### *Architectural*

The 160-person accommodation camp capital estimate is based on the actual cost of constructed the first half (80-person) of the facility in 2015. Allowances for furniture and equipment are included in the estimate though not indicated separately.

In addition, a specification and schedule were provided outlining the list of structures, their respective sizes, and methods of construction and function for estimating purposes.

The main workshop complex includes all the general facility requirements and was estimated based on expected footprint size, main elements, and considering local package-type costs for similar structures.

### *Construction and Installation*

Construction and installation costs were estimated in accordance with the project execution plan, where materials and goods are procured separately from the construction and installation. The construction and installation costs are thus based on the cost of teams for the estimated durations required to execute the works (Table 21.3).

**Table 21.3 Construction and Installation Teams**

| Team | Months on Site |
|---|---|
| General Construction (medium-sized team focused on earthworks, concrete and building) | 20 |
| Main Civils | 5 |
| Main Structural, Mechanical, Platework and Piping | 4 |
| General Structural, Mechanical, Platework and Piping (smaller works leading commissioning) | 5 |
| Electrical and Instrumentation | 4 |
| Commissioning Support | 2 |

The cost of accommodation, fuel, electrical power and general site requirements such as medical services are costed in the general provision of such services and not as part of the construction and installation cost.

### *Piping*

Piping with major supply packages are included in the package costs. The piping excluded from equipment package supply constitutes a minor portion of the estimate. Tetra Tech compiled material take-offs from the process and instrumentation diagrams and process plant model and used historical supply and install rates

adjusted for local conditions. Where possible, Tetra Tech rationalised pipe size and material specification to minimise pipe inventory. HDPE is preferred to lined pipe. Heat tracing and lagging are allowed for on long, exposed pipelines.

### *Platework, Tanks, and Liners*

Quantities for all platework and liners for tanks, launders, pump boxes, and chutes, which fall outside lump sum packages, are minor and allowances were made for items outside the packages on estimated quantities multiplied with rates. The minor platework items are estimated to be constructed from site off-cut materials, with larger portions made up on site from raw materials procured directly by the owner.

### *Mobile Process Equipment*

New mobile equipment cost estimates were based on prices paid by Prognoz recently or through a tender process.

### *Communications*

The communications estimate is based on a satellite Internet connection and mobile phones for general site use.

### *Transport Costs*

Transport costs were considered individually for significant items, and further estimated with allowances by items as well as generalised allowances for bulk material transport. Major equipment transport costs were taken from quotations and a further overall lump sum allowance was included to further take into account consideration for the winter road constrictions.

### *Project Currency and Foreign Exchange*

The capital cost estimate is expressed in US dollars. Costs submitted in other currencies were converted to US dollars based on the foreign exchange rates listed in Table 21.4.

**Table 21.4 Foreign Exchange Rates**

| Currency | Currency Conversion | Inverse Rate |
|---|---|---|
| AUD | 0.7255 | 1.378322 |
| CAD | 0.7645 | 1.307993 |
| EUR 1 | 1.1150 | 0.896837 |
| EUR 2 | 1.1146 | 0.897183 |
| EUR 3 | 1.0900 | 0.917431 |
| EUR 4 | 1.0900 | 0.917431 |
| GBP | 1.4452 | 0.691951 |
| GBP 1 | 0.7092 | 1.410000 |
| RUB 1 | 0.0152 | 66.000000 |
| RUB 2 | 0.0152 | 65.736400 |
| RUB 3 | 0.0174 | 57.387900 |

*table continues...*

| Currency | Currency Conversion | Inverse Rate |
|---|---|---|
| RUB 4 | 0.0152 | 65.920143 |
| RUB 5 | 0.0152 | 66.000000 |
| RUB 6 | 0.0155 | 64.340000 |
| RUB 7 | 0.0155 | 64.590000 |
| RUB 8 | 0.0127 | 79.000000 |
| RUB 9 | 0.0163 | 61.313756 |
| RUB A | 0.0167 | 60.034100 |
| RUB B | 0.0159 | 63.000000 |
| RUB C | 0.0183 | 54.528500 |
| USD | 1.0000 | 1.000000 |
| ZAR | 0.0638 | 15.678896 |

An allowance was included for the Euro and Ruble at various rates related to respective alternate exchange rates, allowing for instances where a specific contract, agreement or payment is already fixed and the base rate thus not subject to current day fluctuations. The items going forward in Ruble is set at the rate stated for RUB 5 (see Table 21.4, 66 Ruble to the American Dollar).

#### *Duties and Taxes*

Duties and taxes are included in this estimate as part of the project indirect costs.

#### *Measurement System*

The International System of Units (SI) measurement system is the standard measurements system used in this estimate.

#### *Closure Costs*

The activities to perform the majority of the mine closure will use personnel and machinery already accounted for in the operating and capital costs. Earth moving and fabrication of physical barriers, making machinery safe, emptying vessels and moving waste materials to the waste dump will be systematically performed as final production ramps down at the end of mine life.

### 21.1.3 Direct Costs

#### *Open Pit Mining Capital Costs*

The initial capital costs are shown in Table 21.5.

**Table 21.5 Initial Open Pit Capital Costs**

| Area | Cost (US$) |
|---|---|
| **Pre-production** | |
| Labour | 685,539 |
| Blasting | 249,237 |
| Maintenance and Fuel | 1,119,086 |
| Ramp—up | 26,976 |
| **Pre-production Subtotal** | **2,080,838** |
| **Mining Equipment** | |
| Open Pit Engineering Equipment | 577,000 |
| **Total Open Pit Capital Cost** | **2,657,838** |

Sustaining capital costs are estimated at $220 000 for the purchase of a grader in the first year of operation.

### *Underground Mining Capital Costs*

The underground mining capital costs are shown in Table 21.6.

**Table 21.6 Underground Mining Capital Costs**

| Description | Year 3 (US$) | Year 4 (US$ | Year 5 (US$) | Year 6 (US$) | Total (US$) |
|---|---|---|---|---|---|
| Lateral | 1,494,974 | 826,665 | 888,122 | 399,362 | 3,609,123 |
| Raisebore | 399,387 | 247,419 | 303,190 | 1,036,376 | 1,036,376 |
| Surface Infrastructure | - | - | - | - | - |
| Underground Infrastructure | 2,693,318 | - | - | 2,693,318 | 2,693,318 |
| Underground Mobile Equipment | 1,787,061 | 2,965,710 | - | 4,752,71 | 4,752,771 |
| Ventilation System | - | - | - | - | - |
| **Total** | **6,374,740** | **4,039,794** | **974,312** | **702,742** | **12,091,588** |

### *Process Plant*

Tetra Tech provided a detailed equipment list with the description, size, and unit cost for each piece in accordance with the process flow sheets and equipment lists. Budget quotations were obtained for all the following major items based on preliminary specifications. Table 21.8 outlines the major procurement packages. Purchasing contracts have been negotiated and awarded for the regrind mill, filter press, ball mill and the electrowinning packages.

To provide an indication as to the scale of the Project, the key quantities that were derived as part of the feasibility study design are shown in Table 21.7. The actual values may be slightly different following detail design and procurement in the months following completion of the study. The effect of these changes have been discounted in the capital estimate following a review of the project records.

**Table 21.7 Key Quantities**

| Description | Unit | Quantity |
|---|---|---|
| Concrete | $m^3$ | 3,700 |
| Structural Steel | t | 1,200 |
| Platework (excluding leach tanks) | t | 95 |
| Piping | m | 6,500 |
| Electrical and Earthing Cables | m | 47,100 |

Quotations were obtained and analysed from the vendors shown in Table 21.8. Costs from the selected vendor (highlighted in grey) are included in the estimate.

**Table 21.8 Mechanical Equipment Procurement Packages**

| Item | Procurement Package Name | Vendor |
|---|---|---|
| 1 | SB15005 Regrind Mill | Metso Minerals |
| | | Glencore |
| | | Solo Resources |
| | | Outotec |
| | | FLSmidth |
| | | ThyssenKrupp |
| 2 | SB15020 Filter Press | Tenova Delkor |
| | | Bilfinger |
| | | Outotec |
| | | Solo Resources |
| 3 | SB15007 Intense Leach Reactor and Gravity Concentrator | FLSmidth Knelson Technologies |
| | | Outotec CIS |
| | | Solo Resources |
| | | Gekko Systems RSA |
| 4 | SB15002 Electrowinning | Electrometals |
| 5 | SB15012 Crusher Plant | Metso Minerals |
| | | PT MIning |
| | | Citic Heavy Industries |
| | | Austraco HK |
| | | FLSmidth |
| | | Osborn Engineered |
| | | ThyssenKrupp |
| | | Souyz Gornykh Mashin (actual supplier) |
| 6 | SB15021 Thickener | Tenova Delkor SA |
| | | Metso Minerals |
| | | FLSmidth |
| | | Outotec |
| 7 | SB15013 MCC Switchrooms | ABB Ltd (Prognoz) |
| | | Siemens LLC (Prognoz) |
| | | Vostochnaia Technica (Prognoz) |
| | | I-control Consulting |
| | | Denwa Engineering |

*table continues...*

| Item | Procurement Package Name | Vendor |
|---|---|---|
| 8 | SB15001 Ball Mill | FL Smidth |
| | | Outotec |
| | | Thyssenkrupp |
| | | Metso |
| | | Citic |
| 9 | SB15066 Ball Mill Logistics | ICTL Belgium |
| | | SDV South Africa |
| | | STS Logistics Russia |
| | | UTI |

Table 21.9 provides a two-tier summary of the initial capital cost estimate for the processing area by system. Included in each of the elements are the civil, structural and electrical work required to supply and install. Transport of equipment is captured in project indirect costs.

**Table 21.9 Processing Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| **Crushing and Stockpiling** | |
| Primary and Secondary Crusher Package | 510,259 |
| **Grinding** | |
| Ball Mill | 1,105,024 |
| Regrind Mill | 114,185 |
| Conveyors | 805,576 |
| Ancillary Equipment | 351,121 |
| General | 96,505 |
| Subtotal | 2,472,511 |
| **Gravity Concentration and ILR** | |
| Gravity Concentration | 379,071 |
| ILR | 421,359 |
| Subtotal | 800,430 |
| **Leaching** | |
| Tanks | 473,007 |
| Leach Tank Agitator | 289,940 |
| General | 1,439,214 |
| Subtotal | 2,202,161 |
| **Decantation Washing** | |
| Thickening | 7,727 |
| Filter Press | 835,106 |
| General | 327,264 |
| Subtotal | 1,170,097 |
| **Electrowinning and Smelt House** | |
| Electrowinning | 2,996,996 |
| Smelt House | 0 |

*table continues...*

| Area | Cost ($) |
|---|---|
| Subtotal | 2,996,996 |
| **Reagents** | |
| Lime Slaking | 32,470 |
| Flocculant | 11,205 |
| Cyanide Distribution | 12,350 |
| General | 559,401 |
| Subtotal | 615,426 |
| **Plant Infrastructure and Utilities** | |
| Plant Roads | 15,870 |
| Weather Shield | 3,183,685 |
| Subtotal | 3,199,555 |
| **Mobile Equipment** | |
| Materials Handling Equipment | 377,292 |
| **Total Processing Capital Costs** | **14,344,727** |

The short mine life and simplicity of the processing plant does not warrant substantial sustaining capital investment as most components will last the full LOM. An amount of $280,000, approximately 2.0% of the equipment cost, was allowed for in each of the years three and five. An amount of $140,000 was allowed for in the first year of production as a provision for plant optimisation.

### *General Infrastructure and Facilities*

The general infrastructure includes bulk earthworks, roads, power generation, communications, site water management, heating, fire management and ancillary buildings (Table 21.10). Site facilities include buildings and fuel storage (Table 21.11). An allowance of $101,464 is included for upgrade of the off-site port facility at Batamai.

**Table 21.10 Infrastructure Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| **Site Preparations** | |
| Bulk Earthworks | 222,270 |
| **Roads and Access** | |
| Site Roads | 212,770 |
| Crossings | 85,000 |
| Subtotal | 297,770 |
| **Power Generation** | |
| Establishment | 1,259,157 |

*table continues...*

| | |
|---|---|
| Fuel Storage | 0 |
| Subtotal | 1,259,157 |
| **Overall Site Controls and Communications** | |
| Communications | 133,290 |

*table continues...*

| Area | Cost ($) |
|---|---|
| Process Control | 218,182 |
| Subtotal | 351,472 |
| **Site Water Management** | |
| Site Drainage | 50,855 |
| Cleaning Ponds | 26,818 |
| Water Supply | 600,391 |
| Subtotal | 678,054 |
| **Heating** | |
| Boiler | 337,141 |
| **Site Access Controls** | |
| Entrances Security | 36,364 |
| **Fire Management** | |
| Water Supply | 7,091 |
| Equipment | 517,777 |
| Subtotal | 524,868 |
| **Ancillary Buildings** | |
| Office | 10,000 |
| **Total Infrastructure Capital Costs** | **3,717,106** |

**Table 21.11 Site Facilities Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| **Ancillary Buildings** | |
| Accommodation Complex | 3,095,668 |
| Cyanide Store | 28,182 |
| Explosives Storage and Mixing | 105,093 |
| Heavy Vehicle and Maintenance Workshop | 1,184,365 |
| Containerised Store | 61,633 |
| Subtotal | 4,474,941 |
| **Fuel Farm** | |
| Fuel Storage | 821,712 |
| **Mobile Fleet** | |
| Mobile Fleet | 63,636 |
| **Total Site Facilities Capital Costs** | **5,360,289** |

**Table 21.12 Utilities Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| **Overall Electrical** | |
| Distribution | 1,224,075 |
| **Sewerage** | |
| Sewage Collection and Treatment | 62,575 |
| **Water Supply** | |
| Water Supply | 88,370 |
| Raw Water | 33,455 |
| Potable Water | 55,000 |
| Process Water | 68,182 |
| **Subtotal** | **245,007** |
| **Domestic Waste** | |
| Waste Collection and Storage | 9,091 |
| **Compressed Air** | |
| General | 98,423 |
| **Total Utilities Capital Costs** | **1,639,171** |

### *Waste Rock Dumps, Ore Stockpiles, and Flood Protection Berms*

A source of benign waste rock, no permanent ore stockpiles and the year-round low to very low ambient temperature means that these material heaps will not require lining. Any minor earthworks, protections berms, and diversion trenches will be created as required by the Silver Bear site construction team. The cost of this has been incorporated in construction team costs and an extra over allowance for the waste rock dump settlement pond construction.

### *Tailings Management Facility*

SRK has prepared MTOs to allow for the development of a cost estimate for all capital, sustaining capital and operational expenditure items associated with construction of the TMF and clarification pond. The capital and sustaining capital costs have been sub-divided in accordance with Table 21.13.

**Table 21.13 TMF Capital and Sustaining Capital Expenditure Summary**

| Description | Comments |
|---|---|
| Capital Costs (Year -1) | • perimeter bund construction<br>• liner installation<br>• pond excavation<br>• pond lining<br>• front end loader (not costed: will use plant equipment)<br>• pump purchase |
| Sustaining Capita Costs (Year 9) | • closure costs<br>• liner installation<br>• slope regrading<br>• capping installation<br>• topsoiling |

The total initial and sustaining direct capital cost estimates are $1,104,096 and $1,325,776 respectively. In additional provision is made in the estimate for indirect capital costs. As a proportion of the direct cost, an allowance was made in each case for an additional approximately 2% for design engineering, 5% for contractor mobilisation and demobilisation $151,856 contingency on the sustaining capital cost estimates. The contingency for initial capital is calculated within the overall contingency.

### *Mine Closure*

Once the mining operation has stopped and the remaining ore in the stockpiles is processed, machinery and personnel will be reassigned to complete the earthworks required for mine closure. Operating costs of the machinery have taken into account the requirement to keep machinery running when not in active duty to prevent freezing. This time will be utilised for the mine closure activities.

Under Owner's Cost, a cost of $100,000 has been allocated for crew, fuel and equipment to monitor site for 1 year post closure. The personnel will live in the local village and travel to site on a weekly basis to monitor the site and take environmental samples.

| Area | Cost ($) | Notes |
|---|---|---|
| Mining Underground | - | Included in operating costs |
| Mining Open Pit | - | Included in operating costs |
| Process Complex | - | Included in operating costs |
| TMF | 1,325,776 | As detailed above |
| Infrastructure | 100,000 | Crew, fuel and equipment for 1 year monitoring and sampling at site |
| **Total Closure Costs** | **1,425,776** | |

### 21.1.4 INDIRECT COSTS

The indirect capital costs include project indirect costs, EPCM, Owner's cost, and allowances (which consists only of contingency allowance).

Table 21.14 shows the summary of the project indirect costs.

**Table 21.14 Indirect Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| **Construction Facilities** | |
| Temporary Laydown Area | 18,182 |
| **Construction Indirects** | |
| General | 2,231,484 |
| **Spares** | |
| Strategic Spares | 928,570 |
| Stores First Fill | 26,451 |
| Operational Spares | 28,089 |
| Subtotal | 983,110 |
| **Initial Fills** | |
| Reagents | 229,736 |
| General | 103,470 |
| Lubricants | 30,000 |
| Subtotal | 363,206 |
| **Freight and Logistics** | |
| Transport | 4,746,060 |
| Taxes and Duties | 164,437 |
| Subtotal | 4,910,497 |
| **Vendors** | |
| General | 100,000 |
| **Financials** | |
| Insurance | 28,468 |
| Irrecoverable Taxes | 20,000 |
| Subtotal | 48,468 |
| **Construction and Installation** | |
| General | 2,539,364 |
| **Total Indirect Capital Costs** | **11,194,311** |

In addition, SRK estimated that the TMF construction indirect costs for the initial and sustaining capital items will be $93,863 and $70,867 respectively, which is incorporated with the overall project indirects.

Even though the project will be executed in a bespoke owner managed execution strategy, Tetra Tech has categorised the cost associated with engineering, procurement and construction management in a conventional way for ease of comparison. EPCM costs constitute approximately 9,4% of direct capital cost (excluding the mining) and is shown in Table 21.15.

**Table 21.15 Initial Capital EPCM Cost Estimate**

| Area | Cost ($) |
|---|---|
| Engineering and Design | 2,551,767 |
| Procurement and Expediting | 796,461 |
| Construction Management | 58,364 |
| Commissioning | 118,900 |
| **Total EPCM Capital Costs** | **3,525,492** |

SRK estimates that the engineering cost associated with the initial and sustaining capital work will be $26,818 and $20,248, respectively. The $26,818 is included in the initial capital EPCM cost shown in Table 21.15.

### *Owner's Cost*

The Owner's Cost makes allowance for Owner activities associated with the Project, and includes allocations of head office costs for Prognoz in accordance with the significant attention to Project matters by Prognoz.

A general allowance was made for managing and executing the Project. Dedicated allowances were made for insurances and operational readiness.

Table 21.16 shows the summary of the Owner's costs.

**Table 21.16 Owner's Cost Capital Cost Estimate**

| Area | Cost ($) |
|---|---|
| Construction Management | 418,889 |
| General | 29,846 |
| Owner's Cost | 3,283055 |
| Licensing and Permits | 676,776 |
| Commissioning | 118,900 |
| **Total Owner's Cost Capital Costs** | **3,850,690** |

### *Allowances*

Generally allowances include provision for undefined items, incurred contingency, escalation and foreign exchange fluctuation. This project estimate does not provide for escalation beyond Q4 2015, nor for exchange rate fluctuations.

The composite allowance for initial capital contingency is $2,374,759 which is 5% of the capital cost estimate. The contingency percentage for each item in the estimate was individually assessed on the accuracy of quantity measurement, type, scope of work, and price information. The average upwards potential on the costs is 5.1% and the downwards potential is 2.4%. The 5.0% contingency was selected as a full percentage rounded from 5.1.%, with rounding down justified by the downwards potential

The weighted average summary by discipline is shown in Table 21.17.

**Table 21.17 Allowances**

| Discipline | Estimate Amount (USD) | Amount Accuracy Up (USD | Amount Accuracy Down (USD) | Percentage Up (%) | Percentage Down (%) |
|---|---|---|---|---|---|
| Mining | 2,630,862 | 274,626 | -143,453 | 10.4 | -5.5 |
| Mechanical Equipment | 18,006,666 | 496,761 | -238,490 | 2.8 | -1.3 |
| Mobile Equipment | 487,190 | 16,915 | -10,655 | 3.5 | -2.2 |
| Civil and Building | 9,641,920 | 586,590 | -283,913 | 6.1 | -2.9 |
| Structural Steel | 3,189,602 | 117,206 | -62,997 | 3.7 | -2.0 |
| Platework | 658,275 | 31,888 | -16,167 | 4.8 | -2.5 |
| Piping and Valves | 1,025,256 | 40,301 | -25,443 | 3.9 | -2.5 |
| Electrical | 2,634,706 | 290,626 | -146,905 | 11.0 | -5.6 |
| Control and Instrumentation | 1,316,256 | 62,887 | -43,246 | 4.8 | -3.3 |
| Management | 7,877,465 | 514,792 | -152,602 | 6.5 | -1.9 |
| **Total** | **47,486,198** | **2,432,592** | **-1,123,970** | **5.1** | **-2.4** |

The sustaining capital estimate includes the following contingency allowances:

- Underground Mining Equipment (Year 4) $599,746
- Underground Mining Equipment (Year 5) $45,331
- Underground Mining Equipment (Year 6) $34,299
- TMF Closure (Year 7) $151,856.

The estimated contingencies are allowances for undefined items incurred within the defined scope of work covered by the estimate, which cannot be explicitly foreseen or described at the time the estimate is completed due to the lack of complete accurate and detailed information.

The contingency allowance is an integral part of the estimate; it is not to be considered as a compensating factor for estimating inaccuracy, nor is it intended to cover such items as any potential labour disputes, currency fluctuations, escalation, force majeure, or other uncontrolled risk factors. It should be assumed that the contingency amount will be spent over the engineering and construction period.

### 21.1.5 Qualifications – Assumptions and Exclusions

#### *Qualifications*

In developing the capital cost estimate, Tetra Tech made the following assumptions:

- concrete aggregate and suitable backfill material will be sourced locally
- construction activities will be continuous and executed primarily with locally sourced construction and installation teams

- bulk materials such as cement, reinforcing steel, structural steel and plate, cable, cable tray, and piping will be available on site when required.

### *Exclusions*

The following items were excluded from the capital cost estimate:

- cost escalation during construction
- piling foundations other than any costs included in the camp construction actual expense lump sum amount
- airstrip and helipad other than any costs included in the camp construction actual expense lump sum amount
- winter road and maintenance
- new roads outside plant area
- weighbridge
- interest on loans and other financing costs during construction
- schedule delays and associated costs, such as those caused by the following:
  - large scale unexpected ground conditions
  - extraordinary climate events
  - labour disputes
  - receipt of information beyond the control of EPCM team
  - schedule recovery or acceleration
  - financing costs
  - taxes (except as supplied by Owner)
  - cost outside Tetra Tech's battery limits
  - sunk costs
  - research and exploration drilling costs
  - force majeure
  - currency fluctuations.

The following items have been excluded from the capital cost estimate but are included in the financial model:

- sustaining capital
- working capital
- closure costs
- salvage values
- operating costs.

## 21.2 OPERATING COST ESTIMATE

### 21.2.1 SUMMARY

The operating cost estimate for the Project consists of mining, processing, G&A (which includes TMF and site water management costs).

The total LOM average operating cost is estimated to be $158.83/t ore processed. The operating cost estimate is expressed in US dollars, unless specified. Table 21.18 summarises the unit operating costs of each area.

**Table 21.18 LOM Averaged Operating Cost Summary**

| Area | Unit Cost ($/t processed) |
|---|---|
| Mining | 59.61 |
| Processing | 57.06 |
| G&A | 42.16 |
| **Total** | **158.83** |

Note: Total may not add due to rounding.

### 21.2.2 BASIS OF OPERATING COST ESTIMATE

*LABOUR*

The permanent work force for the Project will be as local to Yakutsk as possible, and certainly from within Russia. From time to time, international specialist consultants will be engaged for short periods to resolve specific issues; however, their cost has been accounted for separately.

Personnel on the mine site will work on a four-week-on/four-week-off roster. The on- and off-cycles start when the workers report for duty at and when they are returned to the office in Yakutsk. In general, personnel are only paid during the on-cycle.

In accordance with Russian Federation employment practise, working hours and subsequent remuneration is controlled on a daily basis. The first eight hours are considered normal working hours and are included in the basic wage. The next two hours are paid at one and half the basic rate, and any subsequent hours are paid at double the basic rate. No one is allowed to work a shift of longer than 12 hours for more than two days in a row. The basic rate is based on the annual basic salary earned over 1,968 h/a (the so called norm hours).

Each employee is entitled to 52 days of annual leave of which up to 28 days can be taken during the on-cycle of the work rotation. The remainder is paid leave during the off-cycle. Public holidays falling on the on-cycle will be remunerated at double the basic rate, while those that fall on the off-cycle are unpaid.

Personnel working on the mine site generally fall into three categories: shift workers, day shift workers, and senior management. Personnel from the senior management group are not replaced when they are on the off-cycle, but rely on a senior subordinates or fellow managers to act in their stead. As a result, this group's roster

is staggered to ensure maximum cover by senior personnel is maintained. In general, rosters will be staggered to provide operational continuity and mitigate the risk of severe disruption during flight delays.

Technical services will be common to mining, processing, and infrastructure to minimise redundancy. This is particularly important when providing cover for annual leave and illness.

The cost of each role on the mine site has been calculated to include basic and overtime pay (including income tax and social insurance) and takes into account annual leave, leave replacement cost, public holidays, and the number of people that would have to be employed to cover the shift and roster requirements. For example, the basic annual salary (related to the norm hours) for a plant operator is RUB840,000, whereas the cost of one plant operator shift position is RUB5,375,233 and requires the employment of four people. Table 21.20 shows the list of roles used to estimate the operating cost for the Project.

Labour, tax and social insurance rates were provided by Prognoz.

### *Fuel and Power*

Winterised diesel oil will be used for all internal combustion engines and boilers on site. Fuel will be source from any number of local supplier and transported by truck to site. In Q4 2015 Prognoz paid RUB61,700/t for fuel on site.

The power cost was then estimated using an assumed power cost of $0.21/kWh, which assumes on-site power generation as shown in Table 21.19.

**Table 21.19 Power Generation Cost Estimate**

| Cost Component | Unit | Value |
|---|---|---|
| Generator Fuel Consumption | l/kWh | 0.26 |
| Fuel Price on Site | $/l | 0.77 |
| Power Generation Fuel Cost | $/kWh | 0.20 |
| Power Generation Non-fuel Cost | $/kWh | 0.01 |
| Total Power Generation Cost | $/kWh | 0.21 |

## Table 21.20 Personnel Roles

| Band | Sub-grade | Role | Labour Type | Title | Typical Roles | 2016 Salary incl. Tax and Insurance (RUB/a) | Overtime Rate (RUB/a) | Total Payroll (RUB/a) | Leave Replacement Cost (RUB/a) | Total Cost to Company (RUB/a) | Cost/Shift Position (RUB/a) | Cost/Day Shift Position (RUB/a) | Cost/ Management Position (RUB/a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F | 2 | Policy Making | Top Management | C-Level Management | CEO | - | - | - | - | - | - | - | - |
| | 1 | | | | CFO | - | - | - | - | - | - | - | - |
| E | 3 | Programming | Senior Management | General Manager | General Director | 4,200,000 | 1,539,181 | 5,739,181 | - | 5,739,181 | 22,956,725 | 11,478,363 | 5,739,181 |
| | 2 | | | | Mine Manager/Operations Director | 3,840,000 | 1,407,251 | 5,247,251 | - | 5,247,251 | 20,989,006 | 10,494,503 | 5,247,251 |
| | 1 | | | | Plant Manager | 3,480,000 | 1,275,322 | 4,755,322 | - | 4,755,322 | 19,021,287 | 9,510,643 | 4,755,322 |
| D | 3 | Interpretive | Middle Management | Department Manager, Superintendent | Senior Engineer | 3,000,000 | 1,099,415 | 4,099,415 | - | 4,099,415 | 16,397,661 | 8,198,830 | 4,099,415 |
| | 2 | | | | Engineer | 2,700,000 | 989,474 | 3,689,474 | - | 3,689,474 | 14,757,895 | 7,378,947 | 3,689,474 |
| | 1 | | | | Engineering supervisors/Junior Engineer | 2,400,000 | 879,532 | 3,279,532 | - | 3,279,532 | 13,118,129 | 6,559,064 | 3,279,532 |
| C | 3 | Routine | Skilled | Supervisor, Technician | Foreman/Shift Boss | 1,800,000 | 659,649 | 2,459,649 | 419,940 | 2,879,589 | 11,518,357 | 5,759,178 | 2,879,589 |
| | 2 | | | | Senior Technician | 1,500,000 | 549,708 | 2,049,708 | 349,950 | 2,399,658 | 9,598,631 | 4,799,315 | 2,399,658 |
| | 1 | | | | Technician | 1,200,000 | 439,766 | 1,639,766 | 279,960 | 1,919,726 | 7,678,905 | 3,839,452 | 1,919,726 |
| B | 2 | Automatic | Semi-skilled | Charge hand, Machinist | Operator, Cook, Security, Truck Driver | 840,000 | 307,836 | 1,147,836 | 195,972 | 1,343,808 | 5,375,233 | 2,687,617 | 1,343,808 |
| | 1 | | | | Cook Assistant | 780,000 | 285,848 | 1,065,848 | 181,974 | 1,247,822 | 4,991,288 | 2,495,644 | 1,247,822 |
| A | 2 | Defined | Unskilled | Labourer | Cleaner, Laundry | 660,000 | 241,871 | 901,871 | 153,978 | 1,055,849 | 4,223,398 | 2,111,699 | 1,055,849 |
| | 1 | | | | | 600,000 | 219,883 | 819,883 | 139,980 | 959,863 | 3,839,452 | 1,919,726 | 959,863 |

### 21.2.3 Open Pit Mining

The open pit operating costs have been estimated based on project-specific information provided by Silver Bear, and are described in the following subsections.

#### *Labour Costs*

Silver Bear provided the labour rates in a Patterson scale type format. Positions were allocated a grade and shift roster to generate the monthly cost of position, including burden and all costs Silver Bear. Table 21.21 shows the number of positions for each year, and the cost per month to operate the open pit. Some positions were shared with other cost centres, which accounts for the non-integer values.

**Table 21.21 Open Pit Labour**

| Position | Grade | Shift | 2016 | 2017 | 2018 | 2019 | 2020 | Cost RUB/mo | Cost USD/mo |
|---|---|---|---|---|---|---|---|---|---|
| **Mine Personnel** | | | | | | | | | |
| Drill Operator | B2 | shift | 3.0 | 3.0 | 3.0 | 2.0 | 1.00 | 447,936 | 6,787 |
| Drilling Assistance | B1 | shift | 3.0 | 3.0 | 3.0 | 2.0 | 1.00 | 415,941 | 6,302 |
| Backhoe Operator | B2 | shift | 2.0 | 3.0 | 3.0 | 2.0 | 1.00 | 447,936 | 6,787 |
| Truck Driver | B1 | shift | 6.0 | 9.0 | 9.0 | 8.0 | 3.00 | 415,941 | 6,302 |
| Truck Driver (Road Building) | B1 | day | 1.0 | 1.0 | 1.0 | 1.0 | 1.00 | 207,970 | 3,151 |
| Dozer Operator | B2 | shift | 3.0 | 4.0 | 4.0 | 3.0 | 2.00 | 447,936 | 6,787 |
| Grader Operator | B2 | day | 0.5 | 1.0 | 1.0 | 1.0 | 0.50 | 223,968 | 3,393 |
| Loader Operator | B2 | shift | 0.5 | 0.5 | 0.5 | 0.5 | 0.50 | 447,936 | 6,787 |
| Watercart driver | B1 | day | 1.0 | 1.0 | 1.0 | 1.0 | 1.00 | 207,970 | 3,151 |
| Blaster | C3 | day | 1.0 | 1.0 | 1.0 | 1.0 | 1.00 | 479,932 | 7,272 |
| Blasting Crew | C1 | day | 2.0 | 2.0 | 2.0 | 2.0 | 1.00 | 319,954 | 4,848 |
| Helper | A2 | shift | 2.0 | 2.0 | 2.0 | 2.0 | 1.00 | 351,950 | 5,333 |
| **Mine Personnel Total** | - | - | **25.0** | **30.5** | **30.5** | **25.5** | **14.0** | | |
| **Mine Technical Office** | | | | | | | | | |
| Mining Engineer | D3 | day | 2.0 | 2.0 | 2.0 | 2.0 | 2.00 | 683,236 | 10,352 |
| Geologist | D1 | day | 2.0 | 2.0 | 2.0 | 2.0 | 0.25 | 546,589 | 8,282 |
| Geology Technician | C1 | day | 2.0 | 2.0 | 2.0 | 2.0 | 1.00 | 319,954 | 4,848 |
| Surveyor | C2 | day | 1.0 | 1.0 | 1.0 | 1.0 | 0.25 | 399,943 | 6,060 |
| Survey Crew | B2 | day | 1.0 | 1.0 | 1.0 | 1.0 | 0.50 | 223,968 | 3,393 |
| Labourer | A2 | day | 1.0 | 1.0 | 1.0 | 1.0 | 0.50 | 175,975 | 2,666 |
| **Mine Technical Office Total** | - | - | **9.0** | **9.0** | **9.0** | **9.0** | **4.50** | | |
| **Workshop** | | | | | | | | | |
| Mechanic | C1 | shift | 1.0 | 1.0 | 1.0 | 1.0 | 0.50 | 639,909 | 9,696 |
| Turner and Fitter | C1 | day | 1.0 | 1.0 | 1.0 | 1.0 | 0.50 | 319,954 | 4,848 |
| Field Mechanic | C1 | day | 1.0 | 1.0 | 1.0 | 1.0 | 0.50 | 319,954 | 4,848 |
| **Workshop Total** | – | - | **3.0** | **3.0** | **3.0** | **3.0** | **1.50** | | |
| **Total Open Pit Labour** | - | - | **37** | **42.5** | **42.5** | **37.5** | **20.00** | | |

### *Drilling and Blasting Costs*

Open pit blasting parameters were estimated using the data shown in Table 21.22. The powder factors take into account that ore must be more finely fragmented than the waste material.

**Table 21.22 Open Pit Blasting Parameters**

| Parameter | Unit | Waste | Ore |
|---|---|---|---|
| Hole Diameter | m | 0.076 | 0.076 |
| Burden | m | 1.9 | 2.2 |
| Spacing | m | 2.1 | 2.5 |
| Bench Height | m | 10 | 10 |
| Sub-drill depth | m | 1.216 | 1.216 |
| Volume of Rock to be Broken | $m^3$ | 39.9 | 55 |
| Stemming Length | m | 2.28 | 2.28 |
| Powder Factor | $kg/m^3$ | 0.64 | 0.88 |
| Explosive Weight per hole | kg | 35.00 | 35.00 |
| Tonnes Broken per Blasthole | t | 151.25 | 126.483 |
| Metres Drilled per Blasthole | m | 12.28 | 12.28 |
| Re-drilling | % | 5 | 5 |
| Total Metres Drilled per Tonne of Rock | m | 0.09 | 0.10 |
| Total Holes Drilled per Tonne of Rock | - | 0.0069 | 0.0083 |

The powder factors in Table 21.22, along with local rates provided by Silver Bear, were used to determine the drilling and blasting costs per tonne as shown in Table 21.23.

**Table 21.23 Drilling and Blasting Costs**

| Description | Unit | Waste | Ore |
|---|---|---|---|
| Exchange Rate | RUB/USD | 66 | 66 |
| ANFO | RUB/kg | 50 | 50 |
| | USD/kg | 0.76 | 0.76 |
| Detonator and Fuses | $/hole | 1.52 | 1.52 |
| Booster | $/hole | 0.73 | 0.73 |
| Detonating Cord | $/hole | 1.83 | 1.83 |
| Contingency<br>(5% on damaged ignition items) | $/hole | 0.41 | 0.41 |
| Drill Bit | $/h | 7.9 | 7.9 |
| Shank Adapter | $/h | 3.5 | 3.5 |
| Drill Rods | $/h | 5.1 | 5.1 |
| Couplings | $/h | 2.125 | 2.125 |
| Hammer | $/h | 3.5 | 3.5 |
| **Drill Consumable Cost** | **$/h** | **22.13** | **22.13** |
| | **$/t** | **0.10** | **0.12** |
| **Blasting Cost<br>(excluding labour, maintenance, and fuel)** | **$/t** | **0.22** | **0.26** |

### *Equipment Maintenance and Fuel Costs*

Equipment maintenance and fuel costs are based on the estimated working hours for each unit in the mining fleet. Truck operating hours are based on planned haul distances, cycle times, and number of cycles required to match scheduled production. Excavator operating hours are matched to the number of trucks loading cycle times. Drill rig operating hours were estimated based on the drill and blast calculations shown in Section 5.2.2. During winter months most equipment is assumed to be continually operating to avoid freezing due to the extreme temperatures.

The truck cycle times and fuel usage were estimated using the parameters shown in Table 21.24 combined with haul distance determined by bench location and type of load.

**Table 21.24 Truck Cycle Times and Fuel Usage Parameters**

| Parameter | Unit | Value |
|---|---|---|
| Speed on Bench | km/h | 20.00 |
| Speed on Ramp | km/h | 15.00 |
| Speed on Road (flat) | km/h | 30.00 |
| Speed on WRD | km/h | 30.00 |
| Speed on OSP | km/h | 30.00 |
| Speed on ROM Pad | km/h | 15.00 |
| Heavy Fuel Consumption | l/hr | 28.00 |
| Normal Fuel Consumption | l/hr | 22.00 |
| Idle Fuel Consumption | l/hr | 12.00 |
| Ore Truck Loading Cycle Time | min | 6.00 |
| Ore Truck Dump Cycle Time | min | 0.75 |
| Waste Truck Loading Cycle Time | min | 3.00 |
| Waste Truck Dump Cycle Time | min | 0.75 |

Fuel and maintenance costs were estimated on cost per hour using a delivered-to-site fuel cost from Silver Bear of $0.77/l. The average fuel consumption and maintenance costs are shown in Table 21.25.

**Table 21.25 Fuel Consumption and Maintenance Costs**

| Equipment | Type | Fuel Consumption | Maintenance Spares (USD/h) |
|---|---|---|---|
| Truck | Kraz 65032 | 22 l/h | 8 |
| Backhoe | CAT 336 | 35 l/h | 19 |
| Drill | AtlasCopco T40 | 26 l/h | 31 |
| Trackdozer 1 | CAT D9 | 60 l/h | 48 |
| Trackdozer 2 | CAT D8 | 42 l/h | 26 |
| Grader | CAT 14M | 23 l/h | 26 |
| Water Cart | Ural 4320 | 20 l/h | 10 |
| Service truck | Ural | 12 l/h | 3 |
| Fuel Truck | Ural | 20 l/h | 3 |
| Lowbed truck | Ural | 20 l/h | 3 |
| ANFO Truck | UAZ | 20 l/h | 7 |
| Loader | CAT 950 | 15 l/h | 10 |
| Pickup Truck | UAZ | 15 l/d | 1 |
| Lighting Units | - | 25 l/d | 2 |

### *Leasing Costs*

Leasing costs are based on current monthly leasing costs for existing leased equipment, with the drill rigs assumed to have the same lease costs as the CAT 336 shovel. The CAT D8R lease cost has been pro-rated against the D9R lease cost, based on capital cost. Monthly leasing cost are shown in Table 21.26

**Table 21.26 Monthly Leasing Costs**

| Equipment | Type | Leasing Cost (USD/mo) |
|---|---|---|
| Backhoe | CAT 336 | 2,665 |
| Drill | AtlasCopco T40 | 2,665 |
| Trackdozer 1 | CAT D9 | 6,564 |
| Trackdozer 2 | CAT D8 | 4,400 |
| Grader | CAT 14M | 3,100 |

### *Open Pit Costs*

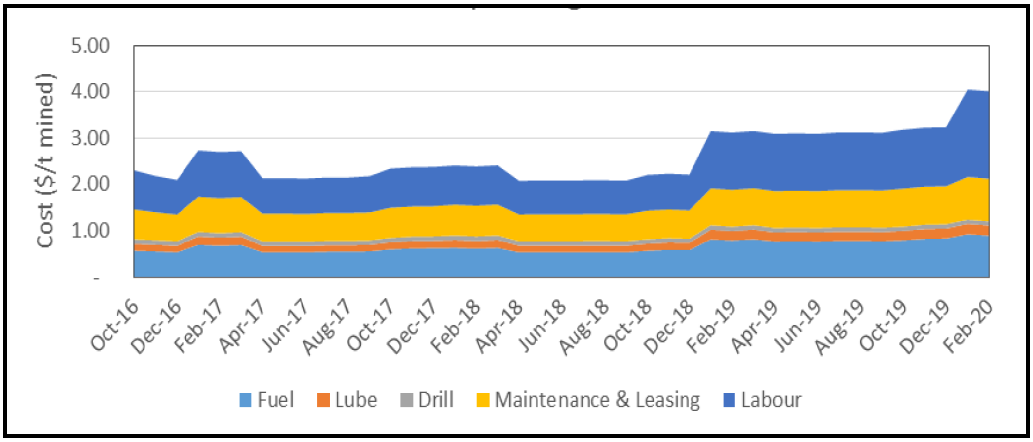
The average mining operating unit costs per tonne of material moved, which includes material moved from the ROM pad to the ROM bin are shown in Table 21.27.

**Table 21.27 Average Open Pit Mining Unit Operating Costs**

| Item | Cost (USD/t mined) |
|---|---|
| Fuel | 0.64 |
| Lube | 0.17 |
| Drill | 0.09 |
| Blast | 0.20 |
| Maintenance | 0.67 |
| Labour | 0.97 |
| **Total Cost per Tonne** | **2.74** |

Figure 21.2 shows how the cost per tonne of material moved changes over the LOM with varying production rates and haulage distances.

**Figure 21.2 Average Open Pit Mining Unit Operating Costs**




## 21.2.4 UNDERGROUND MINING

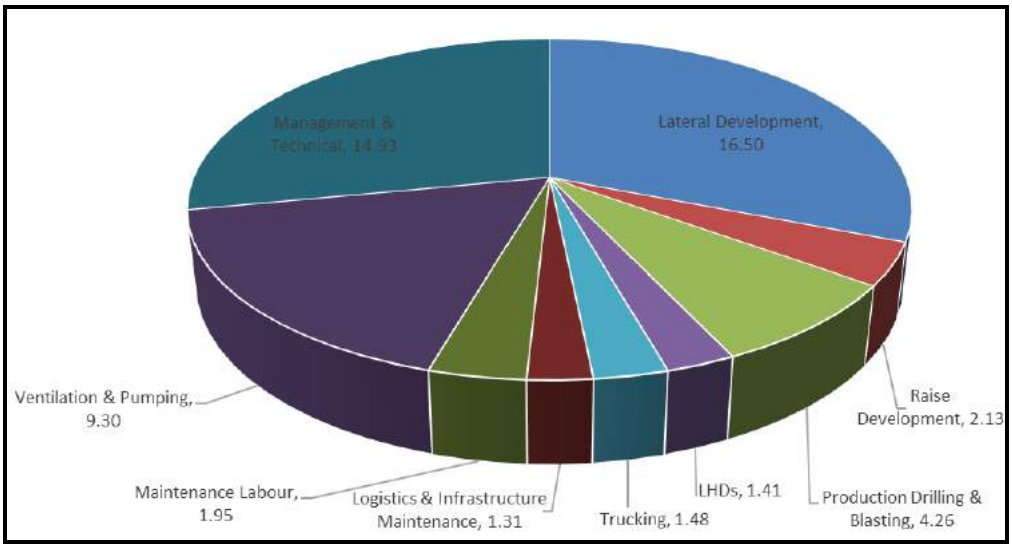
Table 21.28 summarises the underground mine operating costs.

**Table 21.28 Underground Mining Operating Costs**

| Area | Cost (USD/t) |
|---|---|
| Lateral Development | 16.50 |
| Raise Development | 2.13 |
| Production Drilling & Blasting | 4.26 |
| LHDs | 1.41 |
| Trucking | 1.48 |
| Backfill | 0.00 |
| Crushing & Conveying | 0.00 |
| Logistics & Infrastructure Maintenance | 1.31 |
| Maintenance Labour | 1.95 |
| Ventilation & Pumping | 9.30 |
| Management & Technical | 14.93 |
| Total Underground Costs | 53.27 |

The underground mining operating costs are also presented in Figure 21.3.

**Figure 21.3 Underground Mining Operating Costs**




The lateral development costs accounts for approximately 31% of the total underground mining cost, with management and technical staff costs (including the management consumable costs) accounting for another 28% of the total underground mining costs.

The development activities and the management and technical staff should therefore be the focus of cost improvement initiatives pertaining to underground mining at Vertikalny.

### 21.2.5 PROCESS

The process operating cost includes the following estimated components:

- labour (operations and maintenance)
- reagents and consumables (plant)
- maintenance spares
- power.

The total plant operating cost for treating the oxide ore using the proposed flowsheet (Section 17.0) is estimated at $47.58/t. The process operating cast for the primary ore is estimated at $123.71/t.

The process plant operating cost summary for the oxide and primary ores is presented in Table 21.29.

**Table 21.29 Process Plant Unit Operating Cost Summary**

| Area | Unit Cost Oxide Ore ($/t processed) | Unit Cost Primary Ore ($/t processed) |
|---|---|---|
| Labour | 8.28 | 8.28 |
| Reagents and Consumables | 13.68 | 87.31 |
| Maintenance and Spares | 2.17 | 2.17 |
| Power | 23.44 | 25.95 |
| **Total** | **47.58** | **123.71** |

### *LABOUR*

A summary of the process plant labour costs for both the oxide and primary ore is shown in Table 21.30.

**Table 21.30 Plant Labour Cost Estimate**

| Role | Rate Description | Type of Shift | No. of Positions Required | No. of Personnel in Camp | No. of Payroll Personnel | Total Unit Cost (RUB/a) | Total Unit Cost ($/a) | Total Cost ($/a) | Cost ($/t) |
|---|---|---|---|---|---|---|---|---|---|
| Plant Manager | Chief Plant Engineer | Manager | 1 | 1 | 1 | 4,755,322 | 72,050 | 72,050 | 0.66 |
| Metallurgist | Engineer | Day Shift | 1 | 1 | 2 | 7,378,947 | 111,802 | 111,802 | 1.02 |
| Plant Superintendent | Technical Foreman | Day Shift | 1 | 1 | 2 | 5,759,178 | 87,260 | 87,260 | 0.79 |
| Plant Operators | Operations Clerk | Shift | 5 | 10 | 20 | 5,375,233 | 81,443 | 407,215 | 3.70 |
| Electrician | Technician | Day Shift | 1 | 1 | 2 | 3,839,452 | 58,174 | 58,174 | 0.53 |
| Fitter | Technician | Say Shift | 2 | 2 | 4 | 3,839,452 | 58,174 | 116,347 | 1.06 |
| Boiler Maker | Technician | Day Shift | 1 | 1 | 2 | 3,839,452 | 58,174 | 58,174 | 0.53 |
| **Total** | - | - | **12** | **17** | **33** | 34,787,038 | 527,076 | 911,022 | 8.28 |

### *Reagents and Consumables*

Reagent consumptions were estimated based on the feasibility study test work results, from experience in similar projects, or using industry standard assumptions. The annual reagent consumptions were calculated by multiplying the hourly consumptions by the plant operational hours. The unit cost of some of the consumables and reagents were provided by client. Cost data from the Tetra Tech database were used for the remaining consumables, assuming a free on board (FOB) price for delivery in Yakutsk. The shipping cost from Yakutsk to the Project site was applied at a rate of $310/t of material. The summary of the reagent and consumable cost estimation is shown in Table 21.31.

**Table 21.31 Reagent and Consumables Cost Estimate**

| Description | Units | Cons. | Cost ($/unit) | Cons (tons/a) | Cost ($/a) | Shipping Cost ($/a) | Annual Cost ($/a) | Annual Cost ($/t) |
|---|---|---|---|---|---|---|---|---|
| Primary Crusher Liners | set/a | 1 | 25,000 | 3 | 25,000 | 775 | 25,775 | 0.23 |
| Cone Crusher Liners | set/a | 1 | 40,000 | 3 | 40,000 | 775 | 40,775 | 0.37 |
| Mill Liners | kg/t | 0.06 | 5.5 | 6 | 34,130 | 1,603 | 35,733 | 0.32 |
| Grinding Balls | kg/t | 0.7 | 0.64 | 72 | 46,329 | 18,613 | 64,942 | 0.59 |
| ACACIA Operating Cost | /d | 2 | 52 | - | 37,635 | 0 | 37,635 | 0.34 |
| Lime | t | 0.7 | 0.1 | 74 | 9,667 | 19,210 | 28,876 | 0.26 |
| Cyanide | t | 4.6 | 2.23 | 506 | 1,128,634 | 130,746 | 1,259,381 | 11.45 |
| Flocculant | t | 0.03 | 4 | 3 | 11,275 | 710 | 11,985 | 0.11 |
| **Total** | - | - | - | - | - | - | **1,505,103** | **13.68** |

Note: Cons. = consumption

### *Maintenance and Spares*

Maintenance and spares were calculated assuming 3% of the cost of the mechanical equipment. The maintenance and spares cost estimation is shown in Table 21.32.

**Table 21.32 Maintenance and Spares Cost Estimate**

| Description | Unit | Cost |
|---|---|---|
| Mechanical Equipment Cost | $ | 7,963,779 |
| Three percent of Equipment Cost | $ | 238,913 |
| Unit Operating Cost | $/t | 2.17 |

### *Power*

Annual power consumption in was calculated in kilowatt hours by multiplying the absorbed power requirements for each area by the annual hours of operation. The summary of the power cost estimate is shown in Table 21.33.

**Table 21.33 Power Cost Estimate**

| Description | Absorbed Power (kW) | Annual Power Consumption (kWh) | Cost ($/a) | Cost ($/t) |
|---|---|---|---|---|
| Crushing | 148 | 972,360 | 203,223.2 | 1.85 |
| Milling | 786 | 6,048,955 | 1,264,231.6 | 11.49 |
| Gravity Concentration and Intensive Cyanidation | 66 | 528,482 | 110,452.7 | 1.00 |
| Leaching | 404 | 2,770,403 | 579,014.1 | 5.26 |
| Washing and Clarification | 114 | 915,525 | 191,344.8 | 1.74 |
| Electrowinning | 72 | 580,262 | 121,274.8 | 1.10 |
| Sludge Drying | 27 | 135,605 | 28,341.4 | 0.26 |
| Utilities and Reagents | 48 | 386,842 | 80,849.9 | 0.73 |
| **Total** | **1,664** | **12,338,434** | 2,578,733 | 23.44 |

The detailed breakdown of the process operating cost for the primary ore can be seen in Appendix J.

### 21.2.6 TAILINGS MANAGEMENT FACILITY

The operating expenditure components for the TMF have been sub-divided as per Table 21.34.

**Table 21.34 TMF Operating Expenditure Summary**

| Description | Comments |
|---|---|
| Operating Costs (Year 1-8) | • haulage of tailings from plant stockpile, placement, dozer rework to form dry stack facility<br>• clarification pond water treatment<br>• pump costs |

The annual operating expenditure for the TMF is $39,175. This includes costs associated with clarification pond, treatment and pumping of excess fluids from the Clarification Pond.

The costs associated with haulage of tailings from the plant stockpile to the TMF have been captured in the mining operating costs, as the vehicles from the same fleet will be utilized for this task.

The operating costs do not include allowance for environmental waste disposal charges as these are being investigated by the Client. The Mangazieisky tailings have been preliminarily classified as Class III waste which could incur a levy of $7.88/t of tailings.

### 21.2.7 General and Administrative

*Summary*

The average life of mine G&A costs are estimated at $42.16/t processed (Table 21.35) and consist of two components:

- labour – general manager and staffing in accounting, purchasing, and environmental departments, and other G&A departments
- G&A expenses, including insurance, administrative supplies, medical services, legal services, human resources related expenses, travelling, accommodation/camp costs, air crew transportation, and external assay/testing.

**Table 21.35 Average LOM G&A Operating Costs**

| Description | Cost ($/a) | Cost ($/t processed) |
|---|---|---|
| Labour | 1,757,834 | 16.11 |
| Expenses | 2,843,718 | 26.06 |
| **Total** | **4,601,552** | **42.16** |

G&A varies over the mine life and the numbers shown in Table 21.52 are an average.

*Expenses*

G&A expenses vary between $2.7m and $2.9m per year owing to the fact that approximately 70% of the G&A expenses are considered fixed over the LOM. Personnel transport, camp and laboratory costs contribute almost 70% or an average of $1.99 million to the annual G&A cost. The estimate shown in Table 21.36 is based on a nominal number of a 100 people on site.

Tetra Tech estimates that 40 grade control and 10 metallurgical assays will be processed per day at an estimated cost of RUB1,980 per assay, resulting in a total annual cost of RUB36,135,000 (USD240,900).

As a result of runway restrictions the only aircraft available locally that can be used is an Antonov AN-2, single engine biplane with a carrying capacity of 1 t or 10 passengers. The current cost of a charter flight is RUB380,000 per return journey. It is expected that this cost will increase to RUB400,000 to complete the flight all the way to Yakutsk, instead of the smaller territorial runway currently used.

Every four weeks, approximately a 110 people will be flown to and from site at a cost of RUB52,800,000/a. Separate charter flights (using the same AN2) will transport the silver powder product to the refinery and as monthly production will be approximately 6.5 Mt, this will mean between six and seven trips per month for the silver alone. Metal transport costs are discussed in Section 22.7.

**Table 21.36 Average G&A Expense Breakdown**

| Description | Cost ($/a) |
|---|---|
| Clinic | 7,576 |
| External Assay Checks | 45,455 |
| Laboratory | 547,500 |
| Personnel Transport | 800,000 |
| Logistics | 218,182 |
| Light Vehicle Fuel Use | 14,718 |
| IT and Communications | 70,000 |
| Building Maintenance | 9,091 |
| Training | 7,576 |
| Raw Water Supply | 40,129 |
| EMP | 60,606 |
| TMF Operating Cost | 39,175 |
| Corporate | 336,089 |
| Camp | 643,922 |
| **Total** | 2,840,018 |

Logistics expenses comprise warehouse rental and winter road maintenance. Provision is made for RUB225,000 per month for each of the warehouses at Batamai and in Yakutsk and RUB9,000,000 per year is set aside for winter road upkeep, resulting in an estimated annual logistics cost of RUB14,400,000.

Silver Bear will set aside RUB500,000 per year for training.

The estimated annual raw water supply cost of US$40,129 consists mostly of fuel consumption of the power supply (USD36,629) with the balance an allowance for maintenance and sustaining capital.

In the absence of an environmental management plan, Tetra Tech has made an allowance of RUB2,500,000 per year for environmental management measures and, based on advice from Silver Bear obtained from local operations, RUB1,500,000 per year for social compensation. These numbers will be reviewed once the ESIA and resettlement action plan has been completed by ERM.

The corporate expense as been provided by Silver Bear as shown in Table 21.37. Silver Bear estimate that half of this cost is attributable to the Project.

**Table 21.37 Corporate Expenses**

| Component | Cost (RUB/a) |
|---|---|
| Head Office Overhead | 39,046,019 |
| Legal Fees | included in Head Office Overhead |
| Insurance | 931,984 |
| Consultants | included in Head Office Overhead |
| Permitting and Licensing | 4,385,800 |
| **Total** | **44,363,803** |
| **Project** | **22,181,902** |

As the mine site is remote, the vast majority of personnel will be housed in a camp on the mine site. The number of people on the mine site will fluctuate between 51 and 160 over the mine life. Table 21.38 shows the breakdown of the costs for a nominal 100 person camp.

**Table 21.38 Camp Expenses**

| Cost Item | Cost (RUB/a) |
|---|---|
| Subsistence | 36,135,000 |
| Power | 2,863,853 |
| PPE | 500,000 |
| Housewares and Living Supplies | 2,500,000 |
| Camp Maintenance Parts | 500,000 |
| **Total** | 42,498,853 |

The cost of housewares and living supplies was provided by Prognoz who extrapolated from the historical camp costs.

### *LABOUR*

Labour associated with camp operation and maintenance, general maintenance, security and health and safety is included in the G&A costs. A breakdown of the personnel requirements and associated estimated costs are shown in Table 21.39.

Combining the maintenance of vehicles across the mine site will reduce the total number of mechanics employed and eliminate redundancy.

**Table 21.39 G&A Labour Costs**

| Position | Shift | Number of Positions | Job Grade | Unit Cost (RUB/a) | Unit Cost ($/a) | Total Cost ($/a) | Number of Payroll Personnel | Number of Personnel on Site |
|---|---|---|---|---|---|---|---|---|
| Boiler maker | Day Shift | 2 | C1 | 3,839,452 | 58,174 | 116,347 | 4 | 2 |
| Camp Manager | Manager | 1 | D1 | 3,279,532 | 49,690 | 49,690 | 1 | 1 |
| Cleaning Staff | Day Shift | 2 | A1 | 1,919,726 | 29,087 | 58,174 | 4 | 2 |
| Diesel Mechanic | Day Shift | 2 | C1 | 3,839,452 | 58,174 | 116,347 | 4 | 2 |
| General Manager | Manager | 1 | E2 | 5,247,251 | 79,504 | 79,504 | 1 | 1 |
| Electrician | Day Shift | 2 | C1 | 3,839,452 | 58,174 | 116,347 | 4 | 2 |
| Services Engineer | Manager | 1 | D3 | 4,099,415 | 62,112 | 62,112 | 1 | 1 |
| Fitter | Day Shift | 2 | C1 | 3,839,452 | 58,174 | 116,347 | 4 | 2 |
| HSE Officer | Day Shift | 1 | C1 | 3,839,452 | 58,174 | 58,174 | 2 | 1 |
| Cooke | Day Shift | 1 | B2 | 2,687,617 | 40,721 | 40,721 | 2 | 1 |
| Cook's Assistant | Shift | 2 | A2 | 4,223,398 | 63,991 | 127,982 | 8 | 4 |
| Lab Manager | Day Shift | 1 | C3 | 5,759,178 | 87,260 | 87,260 | 2 | 1 |
| Lab Technician | Day Shift | 3 | C1 | 3,839,452 | 58,174 | 174,521 | 6 | 3 |
| Laundry Staff | Day Shift | 2 | A2 | 2,111,699 | 31,995 | 63,991 | 4 | 2 |
| Machine Operator[1] | Day Shift | 2.5 | B2 | 2,687,617 | 40,721 | 40,721 | 5 | 2.5 |
| Doctor | Day Shift | 1 | D1 | 6,559,064 | 99,380 | 99,380 | 2 | 1 |
| Maintenance Planner | Day Shift | 1 | B2 | 2,687,617 | 40,721 | 40,721 | 2 | 1 |
| Security Staff | Shift | 3 | B2 | 5,375,233 | 81,443 | 244,329 | 12 | 6 |
| Warehouse Foreman | Day Shift | 1 | C1 | 3,839,452 | 58,174 | 58,174 | 2 | 1 |
| **Total** | - | **31.5** | - | - | - | 1,706,241 | 70 | 36.5 |

Note: [1]Position shared with mining

# 22.0 ECONOMIC ANALYSIS

An economic evaluation was prepared for the Project based on a pre-tax financial model. The base case uses a variable silver price of $19.65/oz, $18.57/oz, $19.62/oz, $19.79/oz, $19.72/oz, and $19.92/oz during Q1 2017, Q2 2017, Q3/4 2017, 2018, 2019 and 2020, as well as the remaining project life, respectively, with a LOM weighted average silver price of $19.76/oz. The exchange rate applied in the base case is RUB66.00/USD1.00. All currency units are US dollars unless otherwise specified. For the 7.5-year LOM and 822,000 t Mineral Reserve, the following pre-tax financial parameters were calculated:

- 86.1% IRR
- 1.3-year payback on the $50 million initial capital
- $133 million NPV at a 5% discount rate.

Silver Bear commissioned PwC in Toronto, Canada, to prepare tax calculations for use in the post-tax economic evaluation of the Project with the inclusion of applicable Russian income and mining taxes. PwC estimated the applicable taxes in two cases. The first case does not account for the Far East Tax Incentives and the second case takes into account the Far East Tax Incentives (refer to Section 22.4 for further details). The following post-tax financial results were calculated for the base case without considering the Far East Tax Incentives:

- 56.1% IRR
- 1.7-year payback on the $50 million initial capital
- $83 million NPV at a 5% discount rate.

The following post-tax financial results were calculated for the base case when considering the Far East Tax Incentives:

- 81.9% IRR
- 1.3-year payback on the $50 million initial capital
- $123 million NPV at a 5% discount rate.

Sensitivity analyses were conducted to analyze the sensitivity of the Project merit measures (NPV, IRR, and payback periods) to the main inputs.

## 22.1 PRE-TAX FINANCIAL ANALYSIS

### 22.1.1 MINE/METAL PRODUCTION IN FINANCIAL MODEL

The life-of-project average material tonnages, grade, and silver production are shown in Table 22.1.

**Table 22.1 Mine/Metal Production from the Mangazeisky Silver Project**

| Description | Value |
|---|---|
| Total Tonnes to Mill | 821,793 |
| Average Annual Tonnes to Mill | 110,000 |
| Total Waste Tonnes Mined | 10,580,259 |
| LOM (years) | 7.5 |
| **Average Head Grade** | |
| Silver (g/t) | 852 |
| **Total Mill Production** | |
| Silver ('000 oz) | 18,875 |
| **Average Annual Production** | |
| Silver ('000 oz) | 2,520 |

### 22.1.2 Basis of Financial Evaluation

The production schedule has been incorporated into the 100% equity pre-tax financial model to develop the annual recovered silver production from the relationships between tonnage processed, head grades, and recoveries.

Payable silver values were calculated using the base case silver prices. The net invoice value was calculated for each year by subtracting the applicable refining charges from the payable metal value. The at-mine revenues were then estimated by subtracting the transportation and insurance costs. Operating costs for mining, processing, site services, G&A, and others were deducted from the revenues to derive the operating cash flows.

Initial and sustaining capital costs, as well as working capital, have been incorporated over the LOM. Capital expenditures were then deducted from the operating cash flow to determine the net cash flow before taxes.

Initial capital expenditures include costs accumulated prior to the first production of silver; sustaining capital includes expenditures for mining and processing additions, replacement of equipment, and tailings embankment construction.

The pre-production construction period is assumed to be three months. The NPV of the Project was calculated at the beginning of this three-month period.

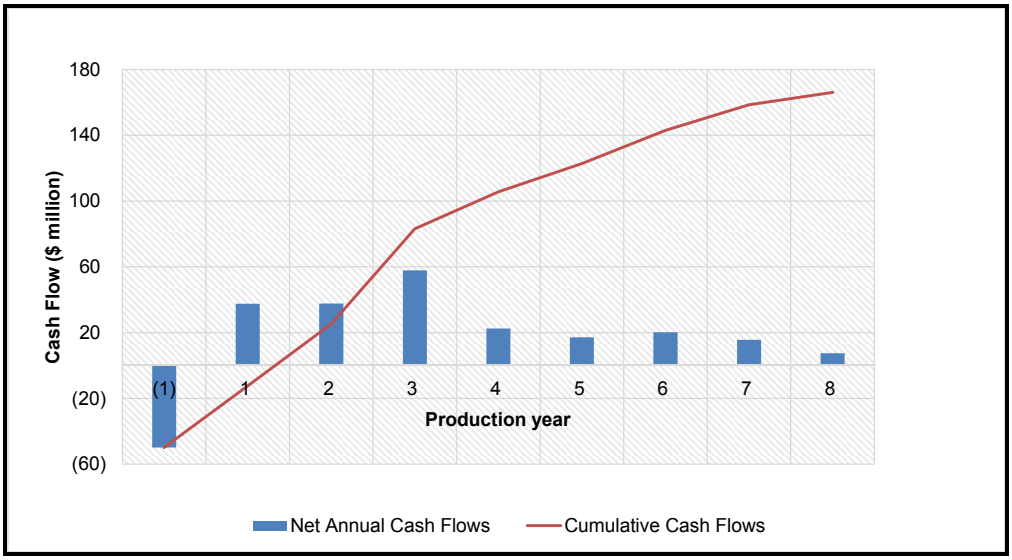
Working capital is assumed to be three months of the annual on-site operating cost and fluctuates from year to year based on the annual operating cost. The working capital would be recovered at the end of the LOM.

Initial and sustaining capital costs during LOM, were estimated at $49.87 million and $15.36 million, respectively.

Mine closure and reclamation costs were not included in the economic analysis.

The undiscounted annual net cash flow (NCF) and cumulative net cash flow (CNCF) are illustrated in Figure 22.1.

**Figure 22.1 Pre-tax Undiscounted Annual and Cumulative Net Cash Flows**




## 22.2 SUMMARY OF FINANCIAL RESULTS

The pre-tax financial model was established on a 100% equity basis, excluding debt financing and loan interest charges. The pre-tax financial results for the base case are presented in Table 22.2.

**Table 22.2 Summary of Pre-tax Financial Results**

| Item | Units | Value |
|---|---|---|
| **Metal Price & Exchange Rate** | | |
| Silver Price (LOM Weighted Average) | USD/oz | 19.76 |
| Exchange Rate | RUB/USD | 66.00 |
| **Net Revenue** | | |
| Recovered Silver | koz | 18,875 |
| Recovered Silver Value | $000 | 372,975 |
| Losses | $000 | 0 |
| Smelter Deductions | koz | 18.9 |
| Smelter Deductions Value | $000 | 373 |
| Payable Silver | koz | 18,856 |
| Payable Silver Value | $000 | 372,602 |
| Refining | $000 | 3,583 |
| Net Invoice Value | $000 | 369,019 |
| Transportation Costs | $000 | 7,005 |
| Insurance | $000 | 240 |
| At-Mine Revenue | $000 | 361,774 |
| Royalty | $000 | 0 |
| Net Revenue | $000 | 361,774 |
| **On-site Operating Costs** | | |
| Mining | $000 | 48,991 |
| Processing | $000 | 46,895 |

*table continues...*

| Item | Units | Value |
|---|---|---|
| G&A | $000 | 34,650 |
| Total on-site operating costs | $000 | 130,536 |
| **Operating Cash Flow** | $000 | 231,239 |
| **Capital Costs** | | |
| Initial | $000 | 49,870 |
| Sustaining | $000 | 15,360 |
| Reclamation | $000 | 0 |
| Total Capital Costs | $000 | 65,230 |
| **Financial Results** | | |
| Pre-tax NCF | $000 | 166,009 |
| Pre-tax NPV at 5% discount rate | $000 | 132,622 |
| Pre-tax IRR | % | 86.1 |
| Pre-Tax Payback | years | 1.3 |
| Cash Cost | $/oz Ag recovered | 7.49 |
| Capital Cost | $/oz Ag recovered | 3.49 |
| Total Cost | $/oz Ag recovered | 10.98 |

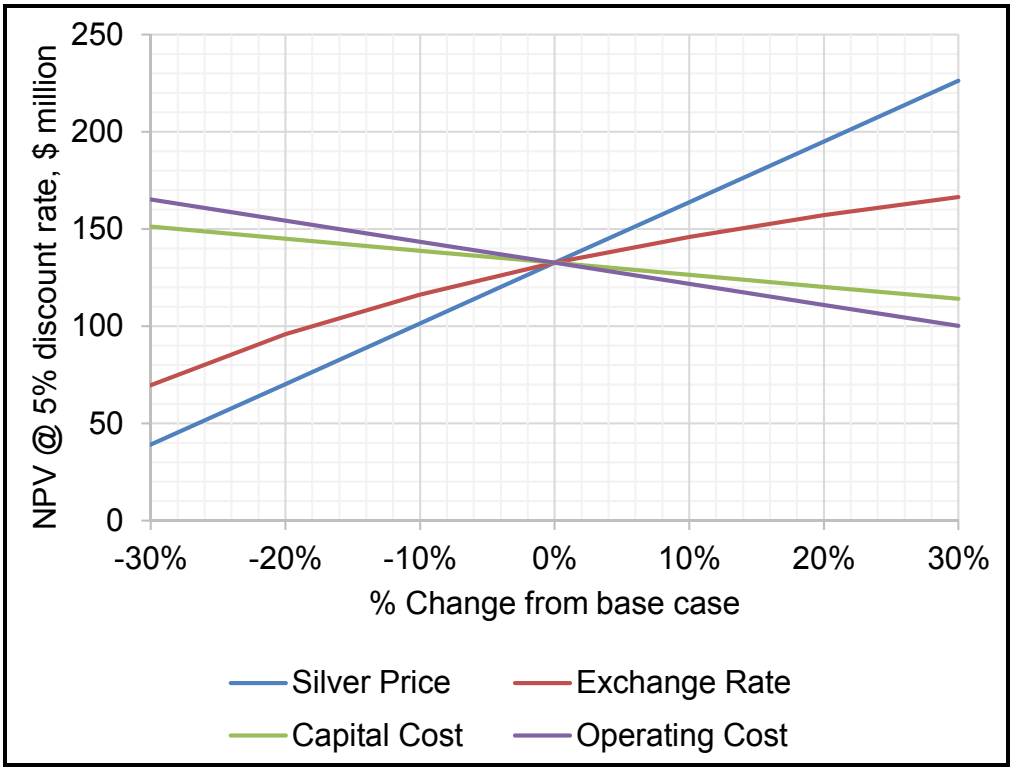
## 22.3 SENSITIVITY ANALYSES

Tetra Tech investigated the sensitivity of NPV, IRR, and payback period to the key project variables. Using the base case as a reference, each of the key variables was changed between -30% and +30% at a 10% interval, while maintaining the other variables constant. The following key variables were investigated:

- silver price
- USD/RUB exchange rate
- capital costs
- on-site operating costs.

The Project's pre-tax NPV, calculated at a 5% discount rate, is most sensitive to silver price followed by exchange rate, on-site operating costs and capital costs, as shown in Figure 22.2.

**Figure 22.2 Pre-tax NPV Sensitivity Analysis**




As shown in Figure 22.3, the Project's pre-tax IRR is most sensitive to silver price followed by exchange rate, capital costs and on-site operating costs.

**Figure 22.3 Pre-tax IRR Sensitivity Analysis**

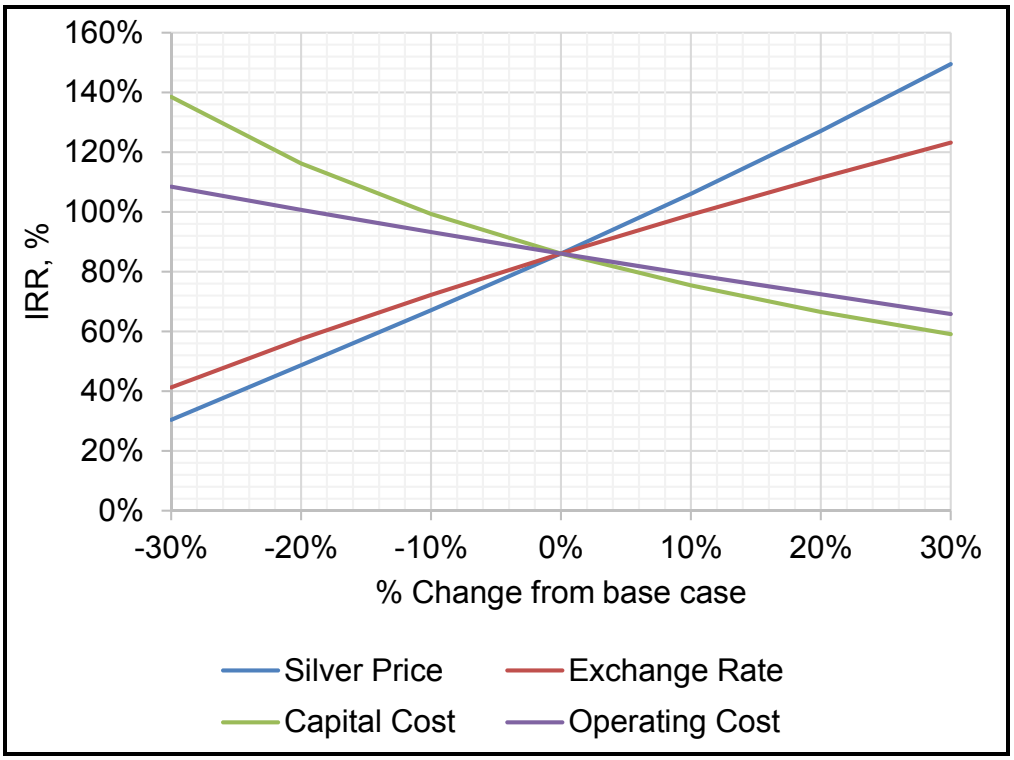
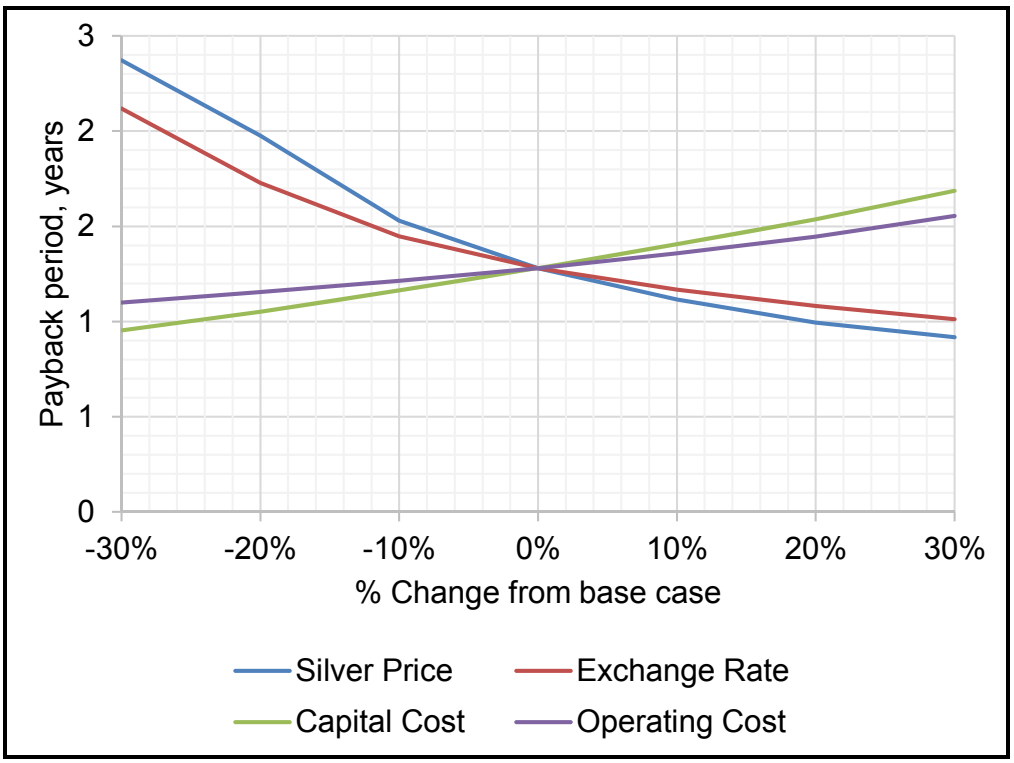


Figure 22.4 shows that the payback period is most sensitive to silver price and exchange rate followed by capital costs and on-site operating costs.

**Figure 22.4 Pre-tax Payback Period Sensitivity Analysis**




## 22.4 POST-TAX FINANCIAL ANALYSIS

Silver Bear engaged PwC in Toronto, Canada to estimate the applicable Russian income and mining taxes for inclusion in the post-tax economic evaluation of the Project. PwC has estimated the applicable taxes in two cases. The first case does not account for the Far East Tax Incentives and the second case takes into account the Far East Tax Incentives.

### 22.4.1 TAX ASSUMPTIONS

PwC prepared the tax estimate for inclusion in the financial model based on the following facts and assumptions, as applicable on 03 October 2016, being the date on which the final draft of the model was prepared for inclusion in the financial analysis.

*PROFIT TAX*

- For the purposes of the profit tax calculation, net revenue (already net of off-site operating costs) less on-site operating costs, which are included in the financial model, were used as the Silver Bear's taxable income before various deductions.
- On-site and off-site operating costs were treated as tax deductible in the period in which they were incurred.

- Capital expenditures may be deducted for profit tax purposed through the depreciation of fixed assets based on their useful lives, which is determined based on the regulations issued by the Russian government. PwC has assumed that the fixed assets will have useful lives that span over the same period as the Project's life, which is eight years as given in the financial model. Actual useful lives of Silver Bear's fixed assets, however, may vary from PwC's assumptions.
- Certain capital expenditures may be depreciated for profit tax purposes in the period the fixed assets are put into operation (called the "depreciation premium"). Depreciation premium may vary from 10 to 30% depending on the nature of the particular fixed asset and its useful life. For the purposes of computing depreciation premium, PwC has assumed that Silver Bear's fixed assets generally have useful lives of 3 to 20 years.
- Sustaining capital costs provided in the financial model were treated as part of the capital expenses that are subject to depreciation for the profit tax purposes, with the assumption that these capital costs are generally related to the renovation of Silver Bear's fixed assets over their useful lives.
- PwC assumed that the working capital included as part of capital expense in the financial mode would not be tax deductible for profit tax purposes. Also, royalties or other concessions that may not have been granted in respect of the Project have been ignored.
- Tax losses accumulated during a particular year may be carried forward and utilized against the taxable profits of Silver Bear. According to the current Russian tax legislation, tax losses can be carried forward for up to 10 years.
- Working capital return in year eight of the Project was assumed to have no Russian tax implications, and hence was ignored.
- PwC assumed the best-case scenario for the application of the Far East Tax Incentives in the tax calculation. The law allows investors to use a reduced rate for profit tax purposes—zero rate for federal tax and a reduced rate for regional tax based on the following time frame:
  - 0 to 10% over the first five years from the year when the initial income from an investment project is received
  - 10 to 18% over the subsequent five years.

The specific regional rates are determined by the laws of the relevant Russian regions. There is a risk that the Yakutia Republic, where the Project is located, may not apply the lowest regional tax rate. PwC applied a reduced regional tax rate to the first year in which Silver Bear generates a taxable profit base for purposes of the tax calculation, but can provide no assurance that this rate will be applicable when the Project enters commercial production.

### *VALUE ADDED TAX)*

- Under the Russian tax legislation, sales of precious metals mined by a taxpayer are subject to 0% output Value Added Tax (VAT) rate.
- Russian input VAT should be paid to the suppliers as part of the price of the goods or services. This amount can then be recovered from the Russian

government. Accordingly, PwC did not include input VAT estimation in the tax calculation as it does not represent at cost to Silver Bear. Cash outflow related to payment and further recovery of input VAT does not usually last for more than six months, but such recovery may not apply to the future. A failure to recover VAT credits on a timely basis may have a material impact on the cash flow of the Project.

### *Mineral Resources Extraction Tax*

- The tax rate of the Mineral Resources Extraction Tax (MRET) established for precious metals (other than gold) is 6.5%. This tax rate applies to the sales value of precious metals mined by the taxpayer during the tax period.
- A zero tax rate would apply to the losses of minerals that are incurred during the mining process within normal limits (the "normative losses"). The limits of losses are established annually by the public authorities to a particular field. Hence, these limits may change by the time the Project enters commercial production.
- For the purposes of the tax calculation in the financial model, PwC assumed the following scenario for the MRT regional tax incentive:
  - 0% of the standard rate is applicable for the first two years of the Project
  - 20% of the standard rate for years 3 and 4 of the Project
  - 40% of the standard rate for years 5 and 6 of the Project
  - 60% of the standard rate for the remaining life of the Project up to year 8.

  PwC cannot provide assurance that these are the rates that will apply to the Project,

### *Property Tax*

- Russian property tax is applicable to the net book value of immovable property at a tax rate of 2.2%.
- All capital expenditures that were considered to be fixed assets and depreciated for profit tax purposes were assumed to be subject to property tax.

### *Taxation of Employees*

- PwC assumed that both personal income tax and social insurance contributions relating to the employees have already been included in the Model as operating expenses. Therefore, PwC has not included these separately in the tax calculation.

### *Application of Far East Incentives*

- PwC assumed that Silver Bear continues to be eligible for the Far East Incentives based on the letter from the Ministry of Economics of Yakutia Republic that was previously provided to PwC on file when performed the previous work in 2014 on the PEA for the same Project. PwC has also assumed that Silver Bear has or will make the corresponding application or

submission of supporting documentation, as required, for this program. PwC was not provided with further information or subsequent determination regarding these incentives for purposes of the profit tax calculation. The receipt of any incentives will depend on future government approval in Russia.

### 22.4.2 Taxes and Post-tax Results

At the base case silver price and exchange rate used for this study, the total estimated taxes payable on the Mangazeisky Project profits over the 7.5-year LOM are $59.05 million, without the Far East Tax Incentives, and $12.01 million with the Far East Tax Incentives. The components of the various taxes that will be payable and the post-tax results for the base case are shown in Table 22.3.

**Table 22.3 Taxes and Post-tax Results**

| Tax Component | Option 1: Without Far East Tax Incentives | Option 2: With Far East Tax Incentives |
|---|---|---|
| LOM Weighted Average Silver Price ($/oz) | 19.76 | 19.76 |
| Exchange rate (USD/RUB) | 66.00 | 66.00 |
| Property Tax ($ million) | 6.13 | 6.13 |
| MERT Tax ($ million) | 23.53 | 5.24 |
| Profits Tax ($ million) | 29.39 | 0.64 |
| Total Tax ($ million) | 59.05 | 12.01 |
| NCF ($ million) | 106.96 | 154.00 |
| NPV @ 5% Discount Rate ($ million) | 82.82 | 123.08 |
| IRR (%) | 56.1 | 81.9 |
| Payback Period (Year) | 1.7 | 1.3 |

## 22.5 Royalties

Tetra Tech relied on Silver Bear to provide the royalties for the economic analysis of the Project. Silver Bear confirmed that there is no any private royalties applicable to the Project.

## 22.6 Smelter Terms

Tetra Tech relied on Silver Bear to provide the smelting and refining terms applicable. The following refining terms were applied in the financial analysis:

- percent payment: 99.9% of delivered silver
- refining charge: $0.19/oz of payable silver.

## 22.7 TRANSPORTATION AND LOGISTICS

Tetra Tech relied on Silver Bear to provide the following transportation costs:

- cost per flight from mine site to Yakutsk: RUB400,000/trip, weekly
- cost of flight from Yakutsk to refinery: RUB200,000/t of silver
- cost of transport to off-take entity: RUB320,000/t of silver.

## 22.8 INSURANCE

Tetra Tech relied on Silver Bear to provide the insurance cost of $30,000/year.

# 23.0 ADJACENT PROPERTIES

There are no adjacent properties.

# 24.0 OTHER RELEVANT DATA AND INFORMATION

## 24.1 PROJECT EXECUTION PLAN

The project execution plan (PEP) is a project document that describes the relationship between engineering, procurement, and construction management activities. The PEP establishes a plan that is integral to the organization strategy and requirements, to manage and control the delivery of a project in a safe and cost-effective manner, and is intended to:

- provide a brief description of the proposed approach to project execution
- outline effective safety and quality methods
- anticipate and reduce or offset scheduling issues
- provide an approach and a description of the requirements for design and EPCM
- limit or avoid capital cost overruns
- anticipate issues related to construction during the design process
- provide a plan for overall project risk management
- outline how vendors and contractors will deliver quality products and services
- address delivery times for long-lead items on the critical path
- identify effective methods for forecasting, reporting, and controlling costs
- develop a detailed plan for project pre-commissioning, commissioning, and handover
- outline project safety management
- address QA/QC requirements and provide a brief project QA/QC plan
- develop the following PEP-related documents:
  - program schedule
  - Prognoz operating manual.

### 24.1.1 SCOPE OF WORK

Silver Bear intends to create a mine, and associated processing facility, to exploit the vertical vane of silver mineralisation in the Vertikalny deposit within their property license area. The scope of the Project extends to the development of all on-site infrastructure and facilities, as well as provision for off-site facilities such as

administration offices in Yakutsk, warehouse facilities along the winter road from Yakutsk to the mine site, and silver metal storage and handling facilities.

The Project scope of work includes the procurement of engineering, fabrication, supply, and construction services, to design and specify all equipment, civil and structural features, electrical supply, and reticulation features and control systems. The major areas include:

- on site:
  - open pit and underground mine
  - metallurgical processing facility
  - associated on-site infrastructure
  - TMF
  - waste rock dumps and ore stockpiles
  - site roads
  - power supply
  - camp
- off site:
  - Yakutsk administrative office
  - Yakutsk warehouse and storage facility
  - winter road
  - Batamai port facilities.

#### *Exclusions*

Items specifically excluded from the Project scope of work include:

- exploration
- work associated with the development of adjacent geological targets or resources
- head office activities not associated with the Project
- Silver Bear corporate activities not associated with the Project
- new airstrip.

### 24.1.2 Objectives and Expectations

The immediate objective for Silver Bear is to become a world-class producer of silver from the wholly-owned Prognoz Vertikalny Resource in the shortest period of time. This must be achieved whilst continuing strategic exploration works, and evaluating and developing additional resources for Silver Bear's continuous growth at optimised capital and operating costs.

#### *Goals and Expectations*

The Project will be planned and executed to meet the following goals and expectations:

- Provision for future expansion:
  - The Project has been designed to exploit the Vertikalny deposit and work has already begun on finding opportunities to introduce ore from satellite deposits. A provision will be made in all areas of the design and construction to allow for future modifications and additions; specifically, space will be allocated adjacent to the processing facility to allow for a concentrator building.
- Financial performance:
  - The Project will be executed for less than $50 million, provide a payback of less than two years, and provide an IRR in excess of 35%.
- Fast track:
  - The final study phases and project execution will happen concurrently. The execution of traditionally sequential tasks need to be overlapped in order to shorten delivery time.
- Sustainable development:
  - The Mangazeisky Silver Program seeks to exploit the Mineral Resources under license to the mutual benefit of the community and Silver Bear investors. The Project forms part of this strategy, and seeks to develop the mine in a responsible and sustainable manner.

#### *Key Performance Indicators*

Key performance indicators (KPI) outline the factors that are crucial to the success of a project. The Project KPI are shown in Table 24.1.

**Table 24.1 Key Performance Indicators**

| KPI | Unit | Value |
|---|---|---|
| Mining Production Rate | kt/a | 110 |
| Plant Availability | - | >0.80 |
| Metallurgical Recovery | - | >0.80 |
| Total Operating Cost | $/t processed | <55.00 |
| Environment | - | minimise harm and impact |

### 24.1.3 Project Constraints

#### *Intent*

The Project forms part of the Mangazeisky Silver Program, which aims to grow the operating asset base of Silver Bear, and provide a return on investment for all shareholders through the extraction of minerals under the license area held by Prognoz. A key outcome for the Project is to deliver a net positive cash flow that will enable Silver Bear to invest in the expansion of operations in the region.

#### *Statutory and Community Requirements*

The execution of the Project, and the associated permit and license applications required, are subject to Russian federal and regional regulatory frameworks. These

frameworks include Gosudarstvennyy Standart (GOST), ROSNEDRA, and the Russian Construction Codes and Regulations (SNiP). Part of the application and approval process includes the submission of formal studies including TEO (feasibility study), Proekt (design documentation), and OVOS (environmental impact assessment).

In addition, Silver Bear, as a TSX-listed public company, subscribes to the international standards of Equator Principles, environmental practice in line with the World Bank and International Finance Corporation (IFC) standards, and the International Cyanide Code.

### *International Trade Embargoes*

The Project is executed in Russia and will be subject to limitations on trade from and with Russia. This includes US embargoes on trade with Russia, and Russian embargoes on trade with Turkey.

### *Project and Site-specific Constraints*

The following constraints apply to the Project:

- Initial capital costs must be less than $50 million.
- All power will be self-generated.
- All fuel will be transported by truck on the winter road and stored on site.
- Extreme winter conditions prevail for approximately nine months of the year.
- Site access for large and heavy loads is limited to the winter road.
- Personnel and small, incidental loads can be flown in by chartered plane or helicopter.
- Water is scarce, available seasonally and mostly locked up in permafrost.

The Project needs to be self-reliant as there is no logistic or infrastructure support in the region.

### *Technology*

The specification and operation of equipment is governed by the extreme weather and the challenging transport logistics. This leads to the following technology constraints:

- Operating mechanical equipment outside requires special provision for the heating of lubricants, fuel, and hydraulic oil. It may not be possible to start and stop machinery in a conventional way.
- The remote location and the impact of adverse weather on flight schedules requires a self-reliant operation with the following features:
  - simplicity
  - conventional, low-tech equipment
  - standardization
  - redundancy

- specification of lower availability.

Where possible, the selection of technology should consider Silver Bear's aim to employ personnel as local to the site as possible.

#### *Language and Culture*

Russian and English are the languages used to execute the Project. Table 24.2 provides a summary of the language used in each phase by each stakeholder.

**Table 24.2 Language Utilisation**

| Description | Silver Bear | Prognoz | EMC | Tetra Tech | ERM | PT Mining | Vendor |
|---|---|---|---|---|---|---|---|
| Internal | English | Russian | Russian | English | English/Russian | Russian | Various |
| Reporting Execution | - | - | Russian | English | English | Russian | English/Russian |
| Operation | English | Russian | - | English | - | - | Russian |

It is acknowledged that there is a difference in culture and professional practice between the stakeholders, and this needs to be taken into account at every phase of the Project. Clear communication of intent and required outcome, without assuming that the other party automatically knows what is expected of them, is essential.

### 24.1.4 Organization and Responsibilities

#### *Overview*

Silver Bear intends to use Russian nationals, specifically people from the Sakha province, to build a team to construct and operate the Project. Specialist skills will be imported from further away where required, and limited to temporary appointments where possible.

The Project will be managed from the Yakutsk administration office; headquarters of Prognoz.

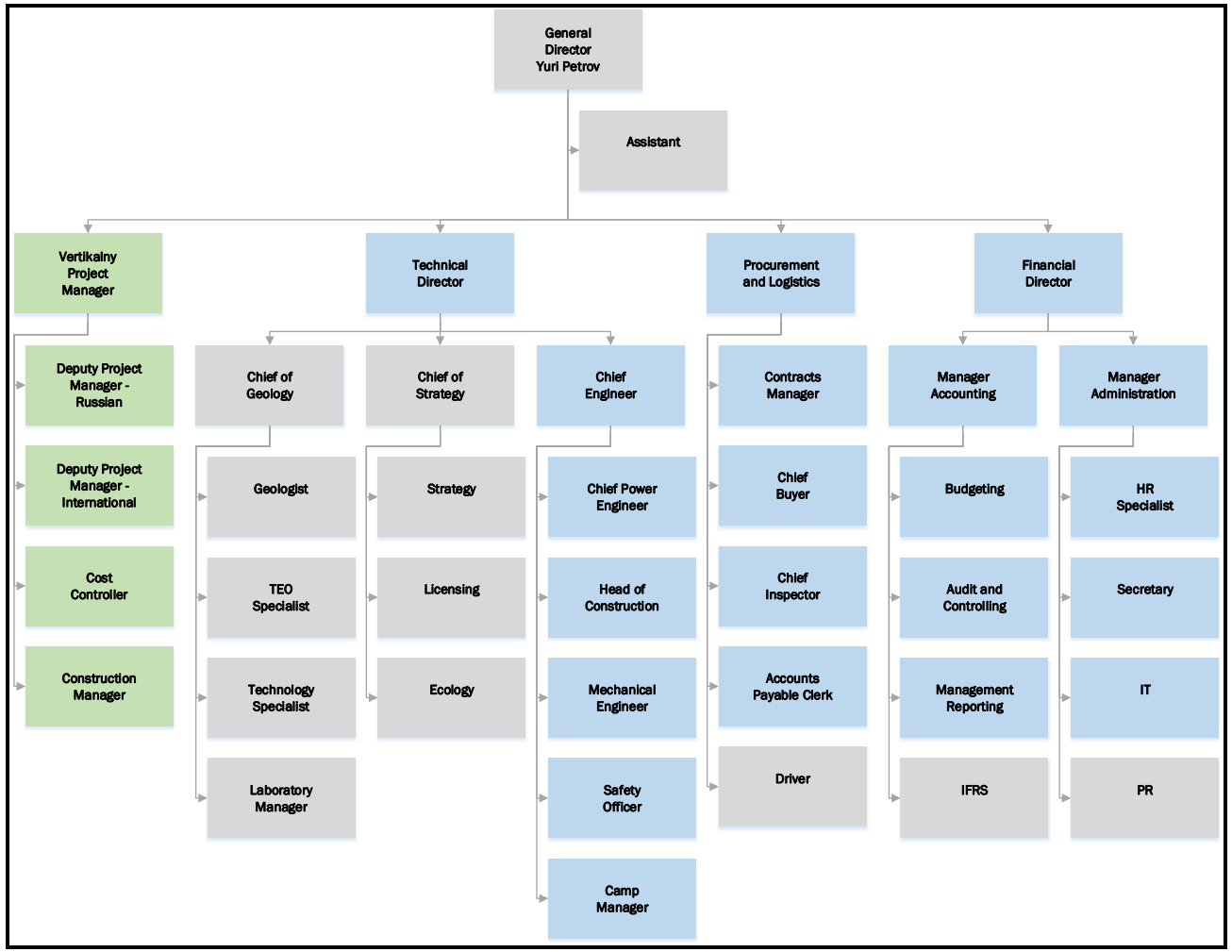
Silver Bear will grow the Project team gradually, starting with a core team during the exploration phase, moving through feasibility with the addition of project management and senior engineering functions, and into execution with further engineering, logistics, procurement, contract management, and construction management roles. Three months before cold commissioning of the process facility, Silver Bear will complete the recruitment of the operational staff to allow for a period of induction and training. Hot commissioning will be completed by the operational staff under the guidance of the on-site consulting engineering team.

#### *Project Organization Structure*

The Silver Bear team will consist of personnel specifically employed to execute the Project, and head office personnel located in Yakutsk allocated to support the Project. Figure 24.1 shows the planned organizational structure for Prognoz. Blue

indicates permanent staff allocated to the Project, and the green denotes new personnel specifically employed for the Project.

## Figure 24.1 Project Organizational Structure



#### *Roles and Responsibilities*

Tetra Tech, an engineering company, currently manages the Project and is employed to engineer, design, procure and project manage in conjunction with the Owner and other participants local to Russia to whom certain procurement packages and responsibilities will be assigned.

The engineering consultant co-ordinates work performed by itself, the local engineering and design institution, sub-consultants, contractors, suppliers and specialists.

The process is engineered by the engineering consultant with vendor inputs, making use of a modular approach with vendor packages.

Prognoz has entered into an arrangement with the St Petersburg based PT Mining procurement of in-country process plant sub-systems.

The roles and responsibilities are summarized in Table 24.3.

**Table 24.3 Roles and Responsibilities**

| Description | Silver Bear | Prognoz | EMC | Tetra Tech | PT Mining | Vendor |
|---|---|---|---|---|---|---|
| Requirement Statement | A | - | C | R | - | - |
| Project Management | A | R | - | C | - | - |
| Basic Engineering | C | - | R | A | - | - |
| Detailed Design | - | C | A | C | R | R |
| Procurement | A | R | C | R | R | - |
| Logistics and Transport | - | A | - | R | R | R |
| Contract Administration | - | A | - | R | R | - |
| Contract Management | A | R | - | I | - | - |
| Construction Installation | - | A | C | - | R | R |
| Payments | A | R | - | C | C | - |
| Project Cost Control | A/R | C | - | C | C | - |
| Quality Management | - | A | - | - | R | R |
| Commissioning | - | A/R | C | C | C | C |
| Ramp-up | - | A/R | C | C | - | - |

Notes: R = responsible; A = accountable; C = consult; I = inform

### 24.1.5 Programme

#### *Staging*

The Project will be executed in a single, fast-track phase.

#### *Programme Constraints*

The key programme constraint is the availability of the winter road between Yakutsk and the Project site, as it provides the baseline opportunity to transport bulk loads (e.g. cement and fuel), as well as heavy and large equipment (e.g. ball mill and filter press).

Unless the required materials of construction and all equipment (except for a few small and light items) are transported during the period the winter road is available, construction will be delayed, unless other potentially costly interventions are implemented.

The basic assumption is that the winter road will be available from 1st December to 15th April each year.

For progress management, two critical paths need to be considered:

- delivering items to site
- construction activity.

IT is critical that the process building (weather shield) will be completed by 30th April 2016. This will allow for rapid construction inside this building and mitigate weather risk events. At the time of writing this report, the foundations for the weather shield had been cast successfully.

### *Approach*

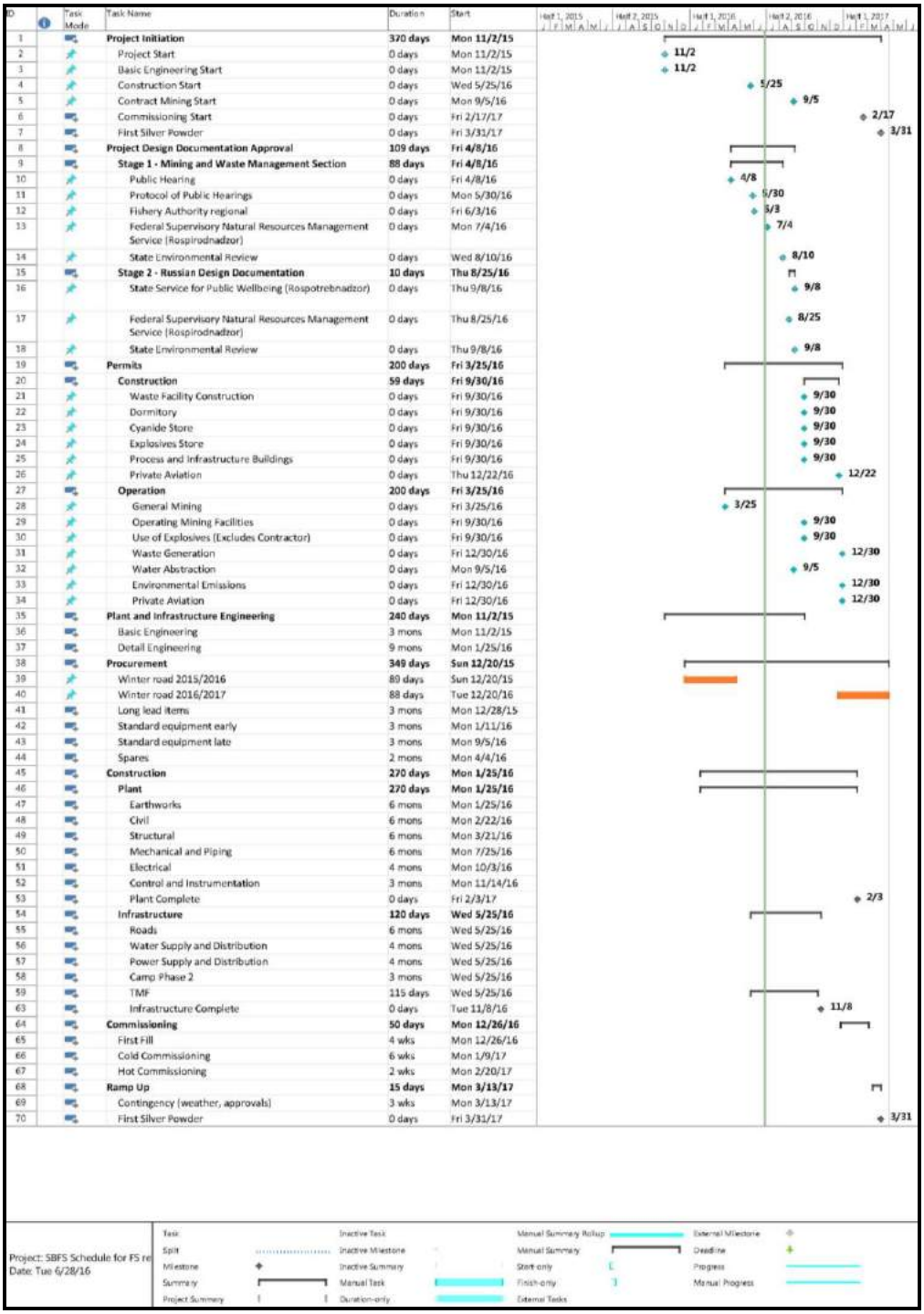
Silver Bear will maintain a master Level 4 EPCM program with Level 3 detail provided by contractors and suppliers to a predetermined work breakdown structure. Contractors will maintain Level 4 schedules, available for review on request.

### *Summary Schedule*

Key programme dates and activities are shown in Figure 24.2. The estimated project completion date is end of Q1 2017.

## Figure 24.2 Mangazeisky Project Schedule

| ID | Task Mode | Task Name | Duration | Start |
|---|---|---|---|---|
| 1 | | **Project Initiation** | **320 days** | **Mon 11/2/15** |
| 2 | | Project Start | 0 days | Mon 11/2/15 |
| 3 | | Basic Engineering Start | 0 days | Mon 11/2/15 |
| 4 | | Construction Start | 0 days | Wed 5/25/16 |
| 5 | | Contract Mining Start | 0 days | Mon 9/5/16 |
| 6 | | Commissioning Start | 0 days | Fri 2/17/17 |
| 7 | | First Silver Powder | 0 days | Fri 3/31/17 |
| 8 | | **Project Design Documentation Approval** | **109 days** | **Fri 4/8/16** |
| 9 | | **Stage 1 - Mining and Waste Management Section** | **88 days** | **Fri 4/8/16** |
| 10 | | Public Hearing | 0 days | Fri 4/8/16 |
| 11 | | Protocol of Public Hearings | 0 days | Mon 5/30/16 |
| 12 | | Fishery Authority regional | 0 days | Fri 6/3/16 |
| 13 | | Federal Supervisory Natural Resources Management Service (Rospirodnadzor) | 0 days | Mon 7/4/16 |
| 14 | | State Environmental Review | 0 days | Wed 8/10/16 |
| 15 | | **Stage 2 - Russian Design Documentation** | **10 days** | **Thu 8/25/16** |
| 16 | | State Service for Public Wellbeing (Rospotrebnadzor) | 0 days | Thu 9/8/16 |
| 17 | | Federal Supervisory Natural Resources Management Service (Rospirodnadzor) | 0 days | Thu 8/25/16 |
| 18 | | State Environmental Review | 0 days | Thu 9/8/16 |
| 19 | | **Permits** | **200 days** | **Fri 3/25/16** |
| 20 | | **Construction** | **59 days** | **Fri 9/30/16** |
| 21 | | Waste Facility Construction | 0 days | Fri 9/30/16 |
| 22 | | Dormitory | 0 days | Fri 9/30/16 |
| 23 | | Cyanide Store | 0 days | Fri 9/30/16 |
| 24 | | Explosives Store | 0 days | Fri 9/30/16 |
| 25 | | Process and Infrastructure Buildings | 0 days | Fri 9/30/16 |
| 26 | | Private Aviation | 0 days | Thu 12/22/16 |
| 27 | | **Operation** | **200 days** | **Fri 3/25/16** |
| 28 | | General Mining | 0 days | Fri 3/25/16 |
| 29 | | Operating Mining Facilities | 0 days | Fri 9/30/16 |
| 30 | | Use of Explosives (Excludes Contractor) | 0 days | Fri 9/30/16 |
| 31 | | Waste Generation | 0 days | Fri 12/30/16 |
| 32 | | Water Abstraction | 0 days | Mon 9/5/16 |
| 33 | | Environmental Emissions | 0 days | Fri 12/30/16 |
| 34 | | Private Aviation | 0 days | Fri 12/30/16 |
| 35 | | **Plant and Infrastructure Engineering** | **240 days** | **Mon 11/2/15** |
| 36 | | Basic Engineering | 3 mons | Mon 11/2/15 |
| 37 | | Detail Engineering | 9 mons | Mon 1/25/16 |
| 38 | | **Procurement** | **349 days** | **Sun 12/20/15** |
| 39 | | Winter road 2015/2016 | 89 days | Sun 12/20/15 |
| 40 | | Winter road 2016/2017 | 88 days | Tue 12/20/16 |
| 41 | | Long lead items | 3 mons | Mon 12/28/15 |
| 42 | | Standard equipment early | 3 mons | Mon 1/11/16 |
| 43 | | Standard equipment late | 3 mons | Mon 9/5/16 |
| 44 | | Spares | 2 mons | Mon 4/4/16 |
| 45 | | **Construction** | **270 days** | **Mon 1/25/16** |
| 46 | | **Plant** | **270 days** | **Mon 1/25/16** |
| 47 | | Earthworks | 6 mons | Mon 1/25/16 |
| 48 | | Civil | 6 mons | Mon 2/22/16 |
| 49 | | Structural | 6 mons | Mon 3/21/16 |
| 50 | | Mechanical and Piping | 6 mons | Mon 7/25/16 |
| 51 | | Electrical | 4 mons | Mon 10/3/16 |
| 52 | | Control and Instrumentation | 3 mons | Mon 11/14/16 |
| 53 | | Plant Complete | 0 days | Fri 2/3/17 |
| 54 | | **Infrastructure** | **120 days** | **Wed 5/25/16** |
| 55 | | Roads | 6 mons | Wed 5/25/16 |
| 56 | | Water Supply and Distribution | 4 mons | Wed 5/25/16 |
| 57 | | Power Supply and Distribution | 4 mons | Wed 5/25/16 |
| 58 | | Camp Phase 2 | 3 mons | Wed 5/25/16 |
| 59 | | TMF | 115 days | Wed 5/25/16 |
| 63 | | Infrastructure Complete | 0 days | Tue 11/8/16 |
| 64 | | **Commissioning** | **50 days** | **Mon 12/26/16** |
| 65 | | First Fill | 4 wks | Mon 12/26/16 |
| 66 | | Cold Commissioning | 6 wks | Mon 1/9/17 |
| 67 | | Hot Commissioning | 2 wks | Mon 2/20/17 |
| 68 | | **Ramp Up** | **15 days** | **Mon 3/13/17** |
| 69 | | Contingency (weather, approvals) | 3 wks | Mon 3/13/17 |
| 70 | | First Silver Powder | 0 days | Fri 3/31/17 |



### 24.1.6 PROJECT EXECUTION

#### *STRATEGY*

The Project is a greenfield project and will be facilitated using Owner-operated equipment and labour to mine the Vertikalny deposit. The deposit will be mined using an open pit operation for the first five years, followed by three years of underground mining. Ore processing will be maintained at an even nominal production rate of 110 kt/a, for optimised economics.

To appropriately schedule and manage these activities, a construction schedule will be developed to incorporate the engineering, procurement, construction and project management activities.

The execution strategy for the successful monitoring and control of the Project reflects a modification to the traditional EPCM approach to project execution. Silver Bear will manage the completion of the Project with the input from various engineering companies, including the St. Petersburg based company EMC, who will do the bulk of the detailed engineering, and Tetra Tech, who will provide engineering review and specialist metallurgical input. Silver Bear will be responsible for the project management, procurement, and construction management using in-house resources. Short lines of decision making will be used to execute this fast-track project.

The Silver Bear execution strategy will be built on a lean, fit-for-purpose approach that favours self-sufficiency in execution and operation.

The engineering contractor and the Owner's team will develop a comprehensive project procedures manual that will outline the procedures and requirements for the execution of the administrative activities related to the Project. The procedures manual will also describe the Owner's and EPCM consultants' or contractors' rights, authorities, and obligations to the Project.

#### *INTERFACES*

Silver Bear, and its subsidiary Prognoz, will have to be mindful of the internal and external interfaces with the Project.

##### *External Interfaces*

External interfaces include local and federal authorities, suppliers, consultants, refineries, contractors, the local communities, shareholders and the Silver Bear Board of Directors.

##### *Internal Interfaces*

The project execution strategy is novel, and will require careful management of interfaces. A reliable, bilingual document management system will be essential in this regard.

**Table 24.4 Project Interfaces**

| Discipline | Responsible | Resourcing | Demarcation |
|---|---|---|---|
| Earthworks | Prognoz | Contracted | Inside mine site |
| Roads | Prognoz | Contracted | |
| Winter Road Upgrade | | | Ongoing operational activity |
| Civil (concrete) | Prognoz | Contracted | Concrete to be purchased from Masc; cement is free-issued; aggregates supplied on site free-issue |
| Main Plant Concrete and Sundry Main Areas | Prognoz | MASS of Yakutsia | |
| Tailings Facility | Prognoz | Contracted | If lining required, special expertise may be required. The lining of TSF must be performed in mild temperatures (greater than minus 5 degree C). |
| Structural Steel | New Structural Steel Contractor | Contracted | included in packages as far as possible |
| Main Process Plant Building | - | - | Erection (under discussion, supplier or current structural constructor) |
| Main Workshop Complex | New Structural Steel Contractor | Contracted | |
| Power Generation Building (if required) | New Structural Steel Contractor | Contracted | |
| Other Buildings | New Structural Steel Contractor | Contracted | |
| Furnishings | Prognoz | - | Bought locally |
| Communications Tower | Mobile Phone Service Provider (?) | Contracted | |
| Power Generation (sets) | Vendor | Contracted | Craneage required by others |
| Power Generation (infrastructure) | Vendor | Contracted | |
| Mechanical Installation | New Mechanical Installation Contractor | Contracted | Some installation checking by package suppliers |
| Electrical and Instrumentation Installation | New Electrical Installation Contractor | Contracted | Look for mechanical/electrical contractor combinations |
| Control Room and Systems Integration | Specialists | Contracted | Integrate between package suppliers |
| Piping | New Mechanical Installation Contractor | Contracted | Exclused plumbing (with building contracts); includes overland piping, interconnecting piping |
| Platework | Ne Structural Steel Contractor | Contracted | Chutes, bins, tank installer involved? |
| Fuel Farm | Specialist Contractor | Contracted | Battery limit: bowzer inlet – discharge nozzle |
| Fuel Farm for Boilers | | Contracted | [check EMC design] |
| Fire Engine Facility | New Structural Steel | Contracted | |

| Discipline | Responsible | Resourcing | Demarcation |
|---|---|---|---|
| (heated) | Contractor | | |

*table continues...*

| | | | |
|---|---|---|---|
| Heat Generator (central heating system) | New Mechanical Contractor | Contracted | Overseen by specialist |
| Localised Heat Source System | Specialist | Contracted | |
| Heat Reticulation | New Mechanical/Piping Contractor | Contracted | |

### 24.1.7 PROJECT CONTROLS

#### *COST CONTROL*

A Silver Bear-appointed consultant based in Moscow will manage project controls at a corporate level using personnel from Prognoz to execute the day to day activities.

The WBS will be used as the initial cost breakdown structure (CBS). The CBS may develop further using the budget deviation procedure as the need arises for more detailed cost splits in particular spots. The link to the WBS will enable continued tracking to the original estimate and the philosophies and information in its formulation.

In order to control costs effectively, the following overriding principles will be followed:

- Cost information, including budget, commitments, and expenditure must be updated on a regular basis.
- All changes to the budget must be approved by appropriate, authorized personnel and formally recorded.
- All information input into a cost control system must be accurate and auditable.
- Expenditure and actual paid must be reconciled at least monthly.

The Silver Bear CEO is the sole approver of budget reallocations, contingency use, and scope changes.

The cost controller is responsible for making changes to any part of a cost element, whether it be budget, commitments, expenditure, or contingency, or to add a cost element if scope changes necessitates such. When making changes to commitments or expenditure the cost controller will effect changes based on documentation, which has been prepared by the procurement department, while any changes to budget or contingency will be based on documentation, which the cost controller is responsible for preparing. This section describes the documentation that needs to be prepared to make changes to any part of a cost element.

A cost element budget, in the control budget or contingency budget, may only be increased or decreased if the appropriate documentation has been completed and approved. Three types of notification and approval situations may be applicable, albeit that these may be executed using the same form. The notification and approval situations are:

- contingency use notice
- budget reallocation notice
- project change notice.

At the start of a project a control budget is established against which project expenditure will be managed. This budget is the best estimate of the future cash flow of the project at the time of establishing the baseline, and assumes a certain exchange rate for the base currency. Unless otherwise agreed with Silver Bear in the cost control plan, currency escalation effects are not included in the control budget and the risk of these changes are managed external to the cost controller. It is the responsibility of the cost controller to accurately isolate and report foreign exchange effects. This will enable Silver Bear to manage risk by:

- taking out forward cover
- making provision in a reserve fund
- in the case of a multinational organization, cover currency movements internally.

Currency escalation is excluded from the contingency budget and additional funds to cover this effect require a project change notice.

The baseline budget of the Project is based on a fixed exchange rate. Actual expenditure is subject to continuous change, and comparing the expense to the baseline budget would not provide a fair reflection of the Project status.

### *SCHEDULE*

The Project will be fast tracked, and therefore time management is crucial. It is effected with

- a Microsoft® Project master program with inputs from other participants and suppliers.
- more detailed fabrication, transport, construction, installation and commissioning program schedules drafted and maintained by suppliers, procurement manager(s), and site management.

The master program does not fully detail all construction and installation activities, but receives inputs from site management who manages a detailed construction and installation program. The master program must be managed such that it delivers two ongoing pieces of key information:

- early warning of critical path slippage
- predicting the Project completion date in a substantiated manner.

The detailed programs should be expected to deliver the same for their particular pieces of the Project.

The winter road access constraint is significantly more critical than the construction and installation planning, and thus the program schedule for the Project has a peculiarity that the critical path and focus requirement is in the detailed planning of procurement, expediting, and transport, with a secondary critical path to be expected in the construction and installation activities.

The master program will be updated weekly and reported with basic printouts and notes to the project manager and a circulation list decided by the project manager. A more comprehensive monthly report will be submitted by the project planner to the project manager. The project planner is an important role in the Project and must have communication skills alongside programming and scheduling skills and experience.

The project planner will communicate any early signals of serious deviations and progress lapses. It is the responsibility of all project participants to report and make the project manager aware of possible time deviations and challenges ongoing and as soon as such possibilities or events are noticed.

The program schedule will be formulated using the WBS and will be used by the cost controllers to assist in early- and long-term cash flow projections (short- and medium-term cash flows are primarily predicted based on detailed supplier or site construction and installation programs).

#### *Engineering Project Controls*

All engineering deliverables shall be peer reviewed and approved by the project engineer. The approved engineering drawings and specifications will be issued for construction and managed through the project document control system. Any change to approved drawings or documents will require the following process:

- description of the scope, cause or motivation, impact, cost and time impact of the change
- provision of a design change request to the project engineer
- if the change can be managed within the engineering budget, the project engineer will manage the approval
- if the change requires budget or schedule change, it will be escalated to the project manager
- an approved design change request will become the basis for a budget and schedule change request.

### 24.1.8 Procurement

Procurement is the process by which goods, materials, and services are obtained from parties outside the client organisation. The objective is to procure such cost-efficiently, at the right time to suit the project program, and to meet the required needs with quality and suitability.

The standard approach for this project will be selected tendering, whereby a list of suppliers will be invited to tender; suitable tender documentation will be issued and the tenders returned will be analysed and compared. The recommended number of tenderers is three to five. Tenders will not be invited from suppliers if there is doubt about the suitability of their product or ability to deliver.

If specialisation or strong client or engineering preference is present, the tender documentation will be issued to a sole supplier and the tender returned, analysed, and accepted once it is clarified and if it is affordable and fulfils the need.

Where there is a significant engineering and design input required on top of specialisation, such that it is not possible to scope the requirement adequately for pre-formatted tendering, negotiations will be entered into directly with one of more suppliers.

Tenders for a particular item will be called for simultaneously and returns required before or on a specific date and time, and place, whether electronically or physically. Electronic (e-mailed) tenders will be acceptable, but place a responsibility on the personnel involved for maintaining confidentiality and to ensure that all tenders are noticed and taken into consideration.

The procurement manager will ensure that a procurement package list is maintained and will issue package numbers to serve as common reference throughout procurement and engagement of the product to the Project.

The tender analysis reports will be taken to the procurement committee in accordance with the client authorisation policy for approval, and smaller cost items will be approved at the appropriate level as allowed by the policy. The authorisation policy may also require items of particular nature to be approved by the procurement committee regardless of cost level.

The contracts manager assigns a contracts administrator to each contract or purchase order. Where the contracts manager has not assigned a contracts administrator, the contracts manager will be default be the contracts administrator. Contract administrators will manage the orderly execution and eventual closure of orders and contracts in a consistent manner.

Where the skills exist locally, priority will be placed local on contractors and contractors hiring local small and medium-sized enterprises for subcontract work.

### 24.1.9 SITE MANAGEMENT

#### *GENERAL*

The Project site near Yakutsk will be under the direct control of Silver Bear's construction manager who will report directly to Silver Bear's CEO. Earth and civil works will be executed by Silver Bear, while contracts will be issued for structural steel erection, mechanical and electrical installation, systems integration and specialist commissioning.

### *Health, Safety, Security and Environment*

Health, safety, security and environment (HSSE) programs and initiatives are essential to overall project success. A fully-integrated program will be implemented to support the objective of a "zero-harm" goal for employees, contractors and visitors working on the Project as well as protecting the environment. To achieve this, key project stakeholders will be responsible for providing the leadership and commitment required to attain the highest standards and values.

A high level of commitment will be required to ensure alignment with site contractors on topics such as safety training, occupational health and hygiene, hazard and risk awareness, safe systems of work, and job safety analysis. The Project will incorporate HSSE as key criteria in the design, constructability, and operability of each facility and major area with the requirement that all personnel must have completed site safety and environmental orientation. Tools will be implemented for performance tracking and accountability, including procedures for incident management.

Construction contractors must be capable of meeting performance objectives with respect to HSSE and security. Hence, additional processes, policies, and procedures will be reviewed and approved in collaboration with the selected contractors to ensure compliance, including:

- pre-tender site safety audit checklists
- preventive maintenance procedures and inspections of tools and equipment
- documented plans for transporting heavy construction components and supplies
- pre-mobilization meeting with Owner's team and contractors
- hazard identification and risk assessment workshops
- project safety management plan audits
- site safety and environmental orientation.

Further, a project health and safety management, environmental, communications, and security plan will be developed by the Project team and the construction contractors. This document will define the systems, procedures, and reporting frequency to be implemented and maintained throughout the Project life. These plans will be controlled and will act as live documents that will be actively used during execution of the Project. Enterprise resource plans (ERPs) will be integral elements of these plans to ensure appropriate actions and communications during non-routine events.

All design and engineering stages incorporate criteria for responsible management of process flows, effluent, and waste products to meet established capture and containment guidelines. The design also incorporates basic clean plant design standards, including operational safety and maintenance access requirements. A hazard and operability (HAZOP) analysis will be conducted by the Project design team during the detailed design stage for each area of the plant to identify and evaluate problems that may present risks to personnel or equipment, or prevent efficient operation. Environmental protection will be incorporated in both the design of the

main processes of the plant, as well as in the transportation, storage, and disposal of materials within and outside the plant boundaries.

### *Site Management Plan*

Silver Bear will be responsible for:

- provision of civil and earthwork construction labour
- provision of civil and earthwork construction equipment
- transportation of all workers from Yakutsk to site and on site
- site offices and temporary services
- site management
- contractor surveying.

The general contractors and subcontractors will be responsible for:

- provision of construction labour
- provision of all construction equipment
- transportation of their workers to Yakutsk
- site management of their works
- QC program – in accordance with the construction technical specifications and the applicable codes and standards
- scheduling and reporting in accordance with the contract
- safety
- security for their tools and equipment
- supplying permanent materials as required by contract
- meaningful project procedures
- commissioning assistance.

The construction management group will be responsible for the management of all field operations. The construction manager will be responsible to plan, organise, and manage construction quality, safety, budget, and schedule objectives.

The construction management field engineering team will employ independent QA assurance specialists to ensure the implementation and success of the contractor's QC.

Detailed construction management responsibilities include, but are not limited to:

- camp management

- camp catering
- camp installation
- insurance, general liability, third party and auto
- labour relations plan and site work rules
- freight logistics and deliveries
- materials handling
- overall project cost system
- scheduling
- site offices
- site topographical survey
- site utilities for field offices
- concrete mix design – with assistance from engineering and procurement
- camp – assist engineering and procurement
- commissioning – assist engineering and procurement
- communications system for construction
- document control – general project and construction
- constructability reviews – with support from engineering and procurement
- spare parts – start-up and commissioning
- vendor representatives (erection support and commissioning) – with assistance from engineering and procurement
- HSSE policy implementation and enforcement
- site construction management
- warehouse and laydown area
- security personnel
- contracting plan
- contract bid documents
- contract tendering – post tender meetings and recommendations
- contract execution and administration
- earthworks and civil site supervision
- mechanical and piping site supervision
- structural site supervision
- electrical and instrumentation site supervision
- commissioning – assist engineering and procurement
- on-site monitoring of construction equipment condition and safe operating capability

- survey and layout
- site QC
- cost reporting and controls – with engineering and procurement
- as-built drawings.

Provision will be made to accommodate a 160-person crew on site during construction. In addition to the total construction labour, it is anticipated there will be approximately 100,000 man-hours of indirect labour associated with construction management, construction camp expansion, site survey, QA, geotechnical support, start-up, and commissioning (including vendor assistance). The Owner's G&A costs outside of the EPCM group hours are not included in this total.

The current full-service, modular, single-story camp will be extended to support the initial construction force for the commencement of bulk earthworks in March 2016 as well as the Owner's personnel including the Owner's construction management team. The growth of the camp will continue in phases as requirements demand to accommodate up to 160 persons overall during peak construction activities including Silver Bear's representatives and visitors.

The camp buildings, located in the Sirelendge Valley, will be a two-storey, clad, wooden frame construction sitting on a steel pipe matrix foundation. The camp will have power, heating, mess and ablutions in working order prior to construction crews arriving on site. All food, and fuel for power generation and heating, will be imported via the winter road meaning that no local timber will be used for heating.

The camp will be single occupancy, and will be provided with recreational facilities. The camp will be designated as a firearm free and dry camp (i.e. no alcohol or non-prescription drugs) area.

The camp will eventually accommodate the Silver Bear's operating personnel (including mining pre-stripping operators). The construction crews working on access road upgrades may opt to provide their own mobile camps to be located where convenient along the route of their work, and their manpower levels are not included in the construction camp sizing.

The construction management team will manage the camp and catering contractor to ensure that quality service is provided including hygiene, food storage and handling, menus and nutritional value, and staff qualifications.

Generally, Silver Bear will be responsible for the supply of all equipment required for construction. No mobile equipment is permitted to operate on site unless it complies with the mining regulations, and no cranes are allowed to operate without recent inspections. Any modifications to equipment have to be certified fit for operation, especially where welding is concerned.

Current on-site estimates indicate there would be quality materials available on or near site which would be hauled to and stockpiled at the crushing/screening plant to be located near the concrete batch plant pad which would be in the general vicinity of the primary crusher. The Silver Bear operated facility will be tasked with producing crushed and screened materials suitable for concrete aggregates.

In addition, the non-acid generating materials will be used in bulk for other areas such as:

- TMF embankment
- clean topping for substation
- engineered backfill for retaining walls
- site road dressing
- piping, electric conduit, and cable trench protective backfill layers.

Permanent power will be made available during the construction period and will supply power for all mine equipment and peak construction power loads for the balance of the construction phase. Any temporary units will be kept on-site until at least the end of the construction period and maintained as emergency power units or operated in some of the more remote environments to replace the contractor's construction units.

During construction, temporary drainage will be installed to collect and store storm water run-off in receiving tanks and to collect and store domestic effluents for treatment in the wastewater treatment facility.

Where construction vehicles are required to park and refuel, hard impervious surfaces will be created to prevent leaching of fuel and fluids into the soil.

Construction plots will be clearly identified and construction works will be kept strictly within these boundaries.

#### *Large Construction Equipment*

The following Silver Bear equipment will be available for general use on site:

- 40-t all-terrain mobile crane
- 25-t all-terrain mobile crane
- 2-t all-terrain forklift
- two Kamaz trucks with conversion as personnel carriers.
- 10-t truck
- two light delivery vehicles.

#### *Construction Consumables*

All cement, water, aggregate, food, fuel, shelter, building consumables and personal protective equipment (PPE) will be free-issued. The batching plant will be controlled by Silver Bear's Construction manager.

Bagged cement will be transported to site on the winter road. The empty bags will be stored in the solid waste storage facility to await proper disposal off site.

Water will be abstracted from the Sirelendge River and transported to the construction site and batch plant by water tanker. Wood for shuttering, formwork and

bracing will be available from the existing timber mill on site using local timber. The timber mill will be controlled by Silver Bear's construction manager.

Materials will be supplied, where possible, from local suppliers.

### *Process Complex Construction*

The majority of the buildings in the process complex will be of steel portal frame construction and clad with Russian-specified and -supplied sandwich panels to provide insulation and weather protection. The steel columns of the portal frame and internal structures will be supported by reinforced concrete plinth foundations below grade. The main floor areas will have 150 mm thick reinforced concrete slab on grade, increasing to 200 mm thick slab for light vehicular traffic areas and 250 mm for high wheel load areas. A temporary system of drainage and wastewater collection will be in place during construction to ensure that run-off and wastewater from the construction site is treated in the site wastewater treatment facility before being discharged to the environment.

Construction preparation will consist of earthworks to level and prepare site to grade, as specified in the detailed design. Plateau levels for the process complex will be largely determined by the topography of the site but in some cases, up to 6 m of cut and fill will be required to create the flat plateaus required for the site. The cut overburden will be crushed and screened by the crushing and screening plant to create an engineered fill for use in raising the ground level where required in creating the plateaus. Building foundations will be excavated to bedrock level to allow for casting of the reinforced concrete plinth foundations. The excavated area will be backfilled with the engineered fill and compacted to grade before casting the reinforced concrete floor slab. Excess overburden not required for engineered fill will be transported to the overburden storage pile where it will remain until utilised at mine closure for site remediation.

The main process plant building will be an 84 m by 24 m steel portal frame structure with an 84 m by 12 m steel lean-to structure attached to the southeast side of the main building. The building will be situated in a northeast to southwest direction to take into account the prevailing north-easterly winds. Internal partition walls in the process plant office complex, reagent mixing area, electrowinning and silver room areas will be masonry.

Noteworthy foundations for the process equipment are the ball mill foundation and leach tank foundations. The ball mill foundation will be constructed from mass concrete, reinforced where required by the structural design and will penetrate the floor slab to take the load to the bedrock, approximately 2 m below grade. The leach tank foundations will be reinforced concrete ring beams penetrating the floor slab and transferring the load to the bedrock.

Where possible, equipment and building elements will be prefabricated off-site. Prefabricated parts and raw material will be shipped to site and stored in secure temporary laydown areas. All fuel, chemicals and reagents for construction will be shipped to site and stored in secure storage. Fuel will be stored in approved fuel pillows and transported around site in approved bowsers with appropriate spillage management kits on hand. Reagents and chemicals will be shipped in sealed and

locked shipping containers and only opened by qualified and trained personnel. Container storage areas will be graded and compacted hard standing.

Further detail on the codes, standards and specifications that will be used in construction can be found in Section 18.5.1. Access road construction is covered in detail in Section 18.6.2.

### 24.1.10 PROJECT COMPLETION

#### *MECHANICAL COMPLETION*

Mechanical completion is a term used to designate that point in time when the contractor is considered to have completed his work such that the facility can be operated in a safe manner. It may not be completely finished at that time, and it could be just systems within the overall project (a building or fresh water system, etc.). Mechanical completion is often descriptive of substantial completion at which time a complete list of deficiencies remaining is developed by the contractor, the construction management team, and the Owner and used to measure the progress to final completion.

Silver Bear will act as the project manager and Owner on the Project. There will be a clear delineation of the roles within the organisation such that the construction team hands over to Silver Bear operational team. This clear differentiation between construction and operation is an essential quality control measure and instils the discipline associated with a client contract relationship. Moreover, this approach is essential to distinguish between capital and operating cost in the Silver Bear accounting system.

Each process system or ancillary facility will be checked for compliance with drawings and specifications, vendor data, and lubrication requirements. Mechanical and electrical capital equipment will be checked for proper installation, alignment, and rotation. Conveyors will be run without load to verify belt alignment. Tanks and piping will be water/air tested. Electrical equipment and circuits will be checked for proper installation. Instrumentation circuits will be checked and instruments will be zero-calibrated. When all installations have been verified, each system will be run under no-load conditions. Permanent records will be maintained for each piece of equipment.

Mechanical completion of systems and facilities is a prelude to the commissioning of the overall plant. By this time the Owner's operating personnel have punch listed the system, and the construction management team has worked with the contractors to finish things up to the state needed. Critical utility features will have been completed before mechanical completion such that water is available for hydro testing of piping and tanks, air is available to test the pneumatics, and permanent power is available to "bump" the motors.

#### *COMMISSIONING*

Existing operations and maintenance personnel will be used at the time of commissioning, testing, and start-up. Subsequent to the commissioning period, scheduled training for supervisors and operations personnel will be scheduled for a two-week period during which a handover to operations will occur. An exact schedule

will be developed in collaboration with the selected contractor during the future work plan phase preceding project execution. As well, a detailed and itemised list of KPIs will be developed to ensure satisfactory performance of the equipment prior to hand off to operations.

Commissioning will be managed by Silver Bear's Owner's team based on the timing as follows:

- Cold commissioning or subsystem level commissioning will be completed by the Silver Bear's project team under the control of the Silver Bear project manager to validate the correct and safe operation of subsystems. No material is used during the commissioning, but for liquid transfer and holding systems, water is often used in lieu of product. Cold commissioning of a subsystem can only commence if all components in the system have been issued with a mechanical completion certificate.
- Hot commissioning follows the completion of all subsystem commissioning and is completed by the Silver Bear permanent operational team of the mine with assistance from the construction team under the leadership of the relevant operational manager. Hot commissioning can only commence if all subsystems have been issued with a cold commissioning certificate.

The sequence of system commissioning is vital to shifting the construction schedule from general area completion to more specific system completion to suit the commissioning and start-up of the entire facility. The commissioning sequence will be developed at the start of the Project. System identification and prioritisation must be expedited to allow for the construction schedule adjustments and the completion of the work, in order to satisfy the established commissioning sequence. During the latter part of construction, the project team will execute the plan based on work priority. Packages will be assembled to include all sign off and test documentation, drawings and vendor information for each system that will be commissioned.

The various systems will be transferred to the Owner's operations team once they are completed and determined by the construction management team to be suitable for safe operation. The Owner's team will consist of plant operators and maintenance staff who will enlist the help of vendors, contractors and construction management personnel as needed to trial the systems until they are finally accepted by the Owner's operations management. The transfer of systems will be formally documented and include all mechanical/electrical testing documents and vendor's information.

### *HANDOVER*

Handover from the Silver Bear project team to the Silver Bear operational team will happen formally at the end of hot commissioning following a performance test. Although an internal handover, the formalization of this step marks the handover of responsibilities and a change in reporting and accounting practice as well as the conversion from a capital to an operational budget.

*CLOSE OUT*

During close out of the Project, the Silver Bear project manager will audit and update all project information including manuals and drawings. The project team will be disbanded and outstanding obligations closed out.

## 24.2 PROJECT RISKS AND OPPORTUNITIES

### 24.2.1 RISKS

A risk matrix was prepared during the feasibility study phase and will be used as the basis to track the risks on the Project and tracked and reported on a monthly basis. The risk matrix will be proactively monitored and mitigation measures implemented to minimise risks during the execution of the Project. The most significant risks (identified as critical risks) related to project execution as identified in the risk matrix are show below with their mitigation strategies.

The main environmental risks associated with the Project are separately assessed and summarised in Section 20.5. In order to minimise the level of risk related to the environmental aspects, health and safety and security measures have been identified. In addition, an ERP will be implemented at the earliest stages of the operation phase to manage those risks that cannot be completely eliminated by the protection measures already in place and to plan emergency interventions if an accident were to occur.

**Table 24.5 Critical Risks**

| Description | Impact | Mitigation |
|---|---|---|
| Delay in critical mechanical equipment fabrication leads to late delivery. | Equipment delivery may miss winter road period and delay the project by a year. | Monitor equipment fabrication and remove any obstacles from fabrication schedule. |
| Delay in critical mechanical equipment freight forwarding. | Equipment delivery may miss winter road period and delay the project by a year. | Appoint specialist logistics consultant to manage overall goods logistics. |
| Delay in receiving sodium cyanide license for procurement. | Sodium cyanide is required to operate the plant. A delay in receiving the license will delay procurement and potentially transport by winter road. | Secure sufficient quantities under supplier license until the next winter road season when Russian paperwork will be in place. |
| Russia closes it borders to supply of goods from Turkey. | Delay in delivery via winter road. | Plan to deliver via another country. |
| Mishandling of sodium cyanide during transport. | Personnel exposed to cyanide resulting in health issues and possible fatality | Only let trained personnel transport sodium cyanide. Double contain the sodium cyanide and have an emergency recovery plan in place. |

| Description | Impact | Mitigation |
|---|---|---|
| Mishandling of sodium cyanide during processing. | Contamination of environment (land and rivers) subject to exposure during a spill. | Only let trained personnel handle sodium cyanide. Train medical personnel on site in sodium cyanide emergency care. Medical evacuation plan. |
| Insufficient water supply due to inadequate season data collection. | Stop operation until water supply is secured. | Conduct full hydrogeological program in the spring. Find alternate winter source of water. |

*table continues...*

| | | |
|---|---|---|
| Data from metallurgical test work done on the samples provided by Silver Bear in 2014 does not reflect mine life ore behaviour. | Predicted recoveries may not be accurate. Lower revenue possible. | Complete metallurgical test work representative of life of mine (see Section 13.0) |
| There is a possible levy on the deposition of tailings in the TMF by the local authorities that relates to the classification of that material. Discussions with the local authorities are ongoing, however there is a possibility that a charge of $7.88/t of tailings may be payable. | An increase in the operating cost of the mine. | According to Silver Bear, the payment of this levy is negotiable, subject to ongoing test work. Silver Bear has committed to ongoing test work and ongoing discussions with the local authorities. |
| Constructing the mine prior to final approvals and permits to construct means that the terms of the approvals may differ from the current design. | Parts of the design and/or constructed facilities may have to be changed leading to extra cost and possible delays. | Employ experienced Russian design agency to design in strict accordance with regulations. Keep the authorities informed and appoint a dedicated team in Yakutsk to manage the design documentation and permit approval process. |
| The approvals and permits for operation may be later than expected. | Without permits to operate the hot commissioning of the plant will be delayed accordingly. | Employ experienced Russian design agency to design in strict accordance with regulations. Keep the authorities informed and appoint a dedicated team in Yakutsk to manage the design documentation and permit approval process. |
| Inability to install the synthetic liner for TMF in low temperatures. | Delay of TMF commissioning. | Proper work scheduling in warmer weather periods. |

### 24.2.2 OPPORTUNITIES

Silver Bear will look to expand their operation by incorporating satellite deposits in the mine license area. The sunk capital cost associated with the infrastructure development for the Project may lower the cut-off grade for subsequent deposits and subsequently the hurdle to entry. The most notable current target is the Mangazeisky North silver deposit.

## 24.3 HYDROGEOLOGY AND WATER SUPPLY

### 24.3.1 SITE CHARACTERISTICS

#### *CLIMATE*

The Project area climate is sharply continental, characterised by large fluctuations in temperature both within the year and during the day. Over the year, the temperature difference between the coldest and the warmest months can reach 58 to 62°C. In winter, the territory is under the predominant influence of the Siberian anticyclone that contributes to overall stable cold weather. In summer, the territory is mainly in a low pressure area. Summer is hot but short, and nights are usually cool; overnight freezing is possible during the summer months.

There is no weather station at the Project site. Descriptions of some of the weather parameters in this section are based on the weather data from the two nearest meteorological stations—Sebyan-Kuel and Syuryen-Kyuyel—which are located south of the Project site, approximately 45 km and 80 km away, respectively. Sebyan-Kuel station has been operating since 2010, and Syuryen-Kyuyel station operated from 1941 to 1988.

#### *Air Temperature*

The average annual temperature according to Sebyan-Kuel and Syuryen-Kyuyel weather stations is -12.5°C and -11.9°C, respectively. The coldest month is January, with average monthly air temperatures of -38.1°C at Sebyan-Kuel and -34.6°C at Syuryen-Kyuyel. The average monthly temperature in July, the warmest month, is +13.7°C at Sebyan-Kuel and +12.7°C at Syuryen-Kyuyel.

#### *Precipitation*

The average annual precipitation at the Sebyan-Kuel and Syuryen-Kyuyel weather stations is 203 mm and 337 mm, respectively. More than 60% of the precipitation occurs during the warm season (May to September). The minimum rainfall over the year is registered in March. The highest average amount of precipitation occurs in June and July (59 mm and 76 mm, respectively) and the lowest in the winter months. Table 24.6 presents data of average monthly and annual precipitation.

**Table 24.6 Average Monthly and Annual Precipitation (mm)**

| Station | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sebyan-Kuel | 3 | 3 | 3 | 8 | 12 | 59 | 39 | 31 | 25 | 13 | 3 | 4 | 203 |
| Syuryen-Kyuyel | 7 | 6 | 5 | 11 | 30 | 67 | 76 | 68 | 38 | 13 | 9 | 7 | 337 |

The first appearance of snow cover occurs typically in September. A stable snow cover forms on average between 28 September and 11 October.

#### *TOPOGRAPHY AND HYDROGRAPHY*

Figure 24.3 illustrates a 3D rendering of the topography and hydrographical network in the Project area. The Property lies in a mountainous region, with elevations

ranging from 800 to 1,400 masl. The main ridges have steep slopes (25 to 30°) and rounded crests that are 200 to 500 m above the valley floors.

The main water course adjacent to the Verticalny deposit is the Sirelendge River, which flows in a northwest to southeast direction into the Arkachan River, approximately 10 km downstream of the Project site. Two local water courses within the Verticalny deposit area flow into Sirelendge River: the Porfirovy and Borisovsky streams. The entire hydrographical network connects to the basin of the Yana River, which flows north into the Laptev Sea. Surface water flow in the area ceases during the winter season due to the freezing temperature, which causes the formation of ice along the river and stream beds.

### 24.3.2 Scope of Site Investigations

#### *Hydrological Field Work*

Surface water monitoring was carried out in three locations:

- the Porfirovy Stream, 5.7 km upstream of its junction with the Sirelendge River
- the Borisovsky Stream, 1.8 km upstream of its junction with the Sirelendge River
- the Sirelendge River, 8 km from the junction with the Arkachan River.

#### *Hydrogeological Field Investigations*

Thermistors were installed in shallow boreholes that were drilled as part of geotechnical investigations. These boreholes, which have an average depth of 30 m, were used to monitor the temperature of the shallow geological formations.

#### *Hydrogeological Boreholes*

Deep hydrogeological boreholes were drilled in the Project area for two purposes:

- Due to freezing of surface waters over approximately eight months of the year, an alternative reliable source of water is needed. The sub-permafrost aquifer was identified as the main target for water supply investigation.
- A deep borehole was drilled into the ore deposit to investigate if parts of the future underground mine will intersect the sub-permafrost aquifer.

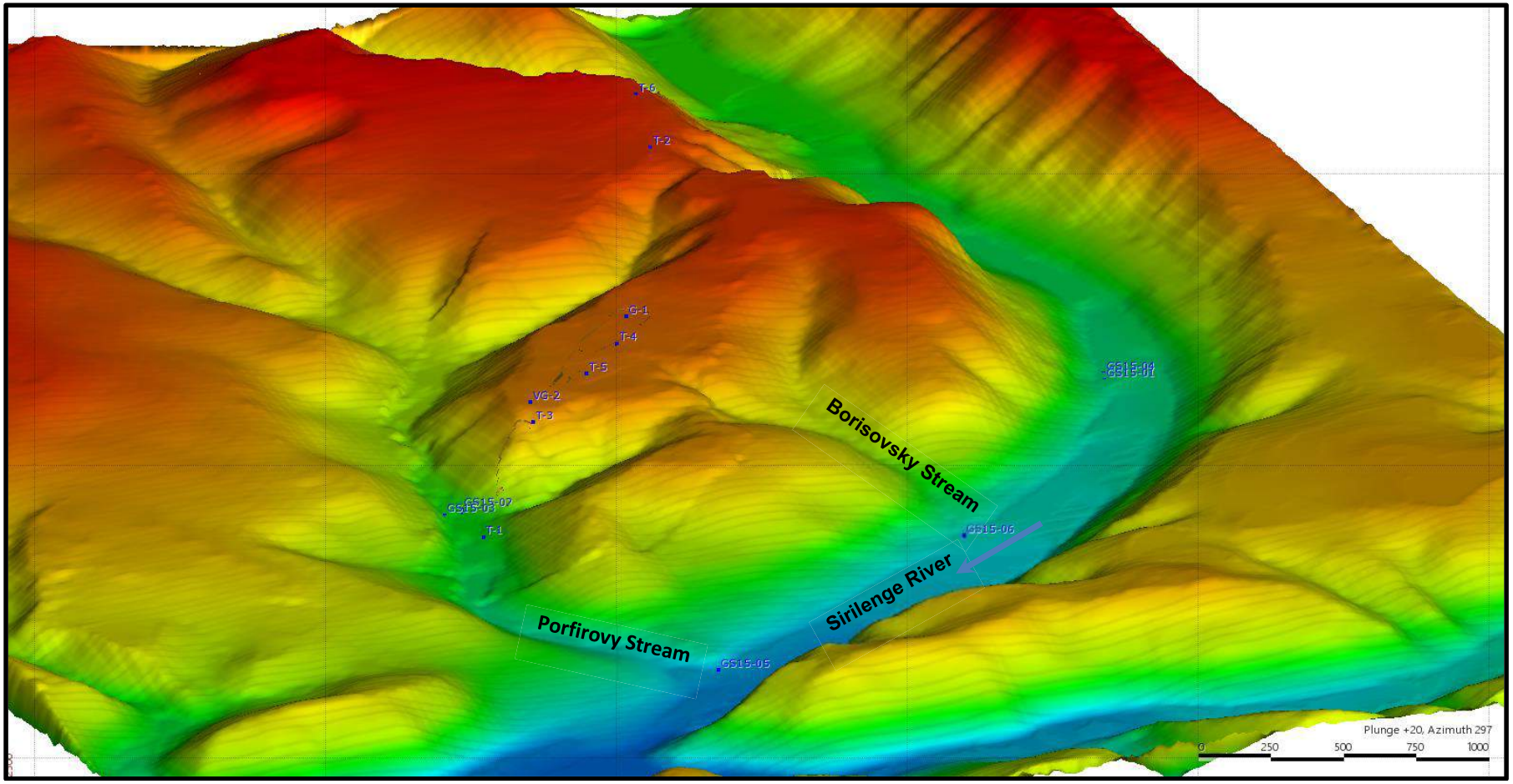
#### *Water Supply Investigations*

Subsequent to the surface geophysical survey, which targeted three areas, locations for water supply investigations were defined for intrusive investigation. The following boreholes were successfully drilled and tested for the water supply investigation: GS15-01, GS15-04, GS15-05, and GS15-06 (Figure 24.3 and Figure 24.9). The four boreholes are located along the Sirelendge River valley, and have a vertical depth of approximately 250 m below ground surface.

Two boreholes, GS15-01 and GS15-04, were drilled and pumping tests completed in June 2015 (Figure 24.3). The third borehole (GS15-05) was drilled and tested in

November, at the junction of the Porfirovy Stream and Sirelendge River. The observed average free flow (without pumping) from GS15-05 was approximately 1.65 L/s. Since the artesian outflow from this borehole exceeded the capacity of the pump that was available on site (1.39 L/s; 5 $m^3$/h), a shut-in test was carried out to monitor water pressure recovery instead of conducting a pumping test.

**Figure 24.3 3D View of the Project Area Topography and Hydrography, Showing Borehole Locations**



Full recovery of water pressure seems to have been achieved during the 77 minute test. After the test, the flow rate was manually measured regularly until the hole froze on 13 November 2015. The artesian flow measurements for borehole GS15-05 are shown in Table 24.7. Before freezing, the borehole was equipped with a string of thermal sensors for geothermal monitoring. The thermal sensors were installed at the following depths: 1, 10, 25, 50, 100, 150, 200 and 230 m.

**Table 24.7 Measured Artesian Outflow Rates in Borehole GS15-05**

| Date | Time | Flow (L/s) | Daily Average (L/s) |
|---|---|---|---|
| 08/11/2015 | 15:25 | 1.64 | 1.64 |
| 10/11/2015 | 08:42 | 1.53 | 1.67 |
| 10/11/2015 | 16:05 | 1.80 | |
| 11/11/2015 | 09:55 | 1.66 | 1.66 |
| 11/11/2015 | 14:00 | 1.64 | |
| 11/11/2015 | 18:00 | 1.67 | |
| 12/11/2015 | 10:00 | 1.57 | 1.51 |
| 12/11/2015 | 14:00 | 1.55 | |
| 12/11/2015 | 17:00 | 1.40 | |
| 13/11/2015 | FROZEN | | |

Borehole GS15-06 was drilled at the junction with Borisovsky Stream, and a pumping test was completed in November 2015. Subsequent to testing, water samples were taken from all four boreholes and sent to laboratory in Yakutsk for analysis.

#### *Mine Hydrogeological Investigations*

Two boreholes (VG-2 and G-1) were drilled and equipped with a string of thermistors in the mine area. The thermistors were allowed enough time to equilibrate before reliable temperature measurements were taken a number of times. Neither of these two holes traversed the full thickness of the permafrost; nevertheless, it was possible to quantify the geothermal gradient using the temperature data collected from the 300 m-deep borehole VG-2, and estimate the permafrost thickness in that location.

### 24.3.3 FIELD DATA ANALYSIS AND MODELLING

#### *SURFACE WATER HYDROLOGY*

#### *Hydrological Catchments and River Flow Rate*

Locations of the stream/river flow monitoring points are shown in Figure 24.4.

**Figure 24.4 Local Hydrological Catchments and Location of Flow Monitoring Points**

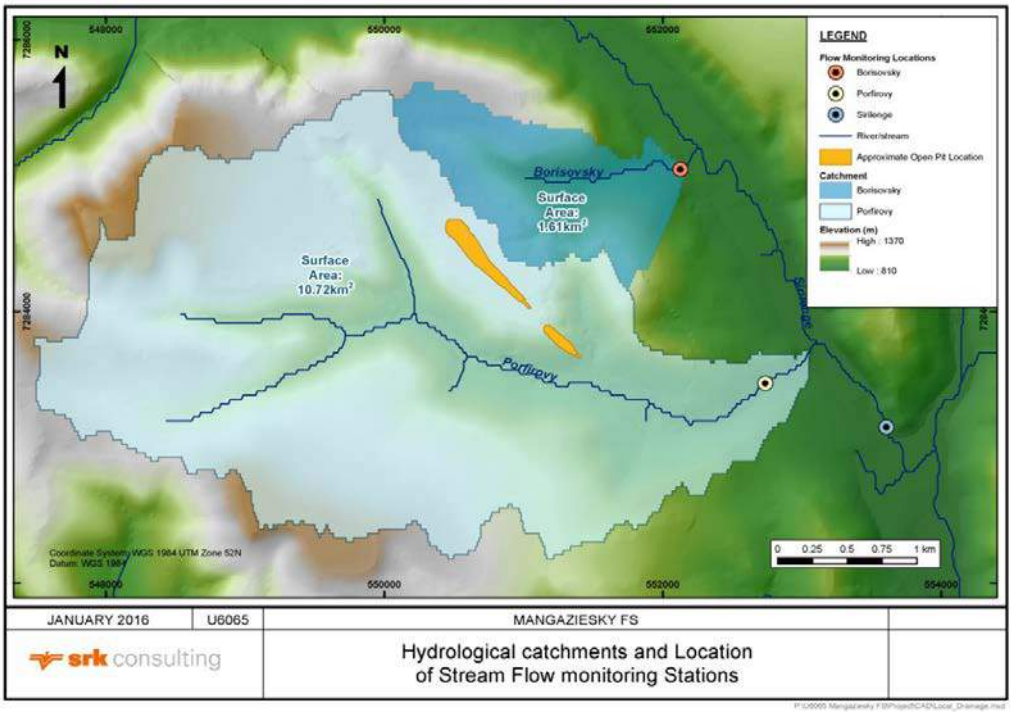
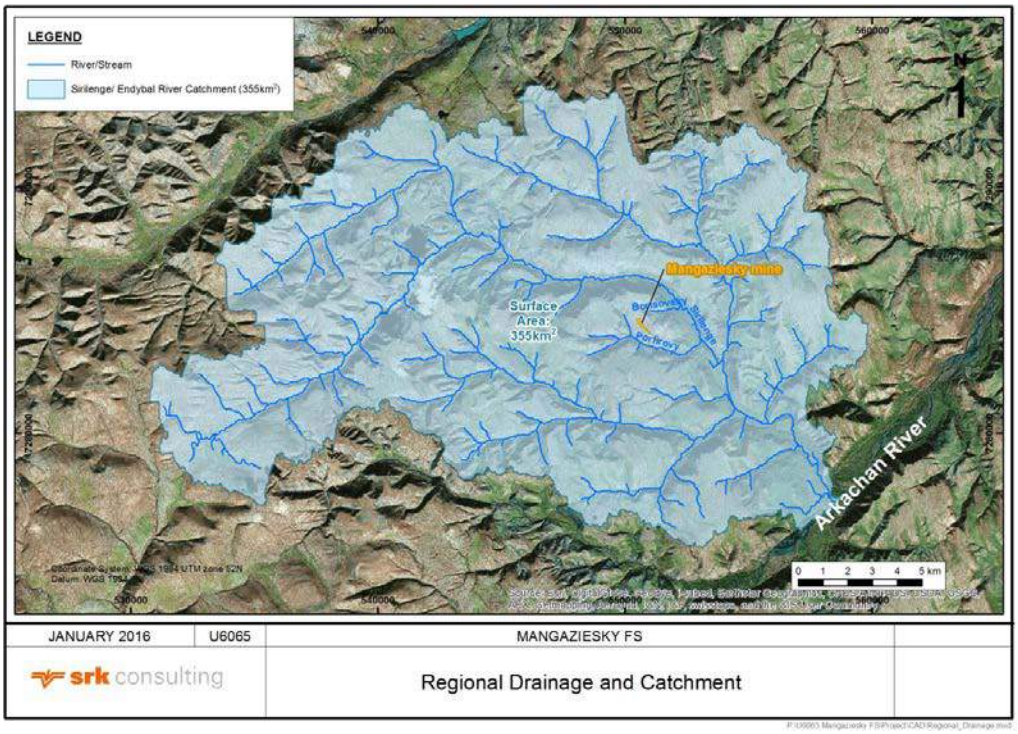



**Figure 24.5 Regional Drainage Catchment**




All four stages of the open pit fall within one sub-catchment, and will drain into the Porfirovy Stream, which is a tributary of the Sirelendge River and has a drainage surface area of approximately 10.7 km$^2$ (Figure 24.4). Draining to the east of the ridge, upon which the pit is located, is the Borisovsky Stream, which is a small

tributary of the Sirelendge River and drains a smaller area of just about 1.6 km². The Sirelendge River flows 10 km downstream into the Arkachan River (Figure 24.5). The total surface area of the river catchment at the Arkachan River confluence is 355 km². The values of the average annual discharge within the three main water courses in the Project area are estimated and summarised in Table 24.8.

**Table 24.8 Average Annual Discharges or Surveyed River Sections**

| Monitoring Point | Watercourse Name | Average Perennial Water Discharge (m³/s) |
|---|---|---|
| 1 | Porfirovy Stream 5.7 km from the mouth | 0.050 |
| 2 | Borisovsky Stream 1.8 km from the mouth | 0.013 |
| 3 | Sirelendge River, 8 km upstream of the junction with Arkachan River | 0.79 |

### *Estimation of Potential Storm Magnitude*

The storm magnitudes for the Project were estimated by SRK using the precipitation data from the Syuryen-Kyuyel station, with a 10% increase applied to these data because of the lengthy distance from the site. For a range of return periods for the station, storm depths were calculated using the annual maxima method which utilises the Gumbel extreme value distribution and a variety of plotting position formulae, including Weibull, Gringorton, Cunnane and Hazen. The results obtained using the Cunnane plotting position formula were adopted for storm water management design for the Project because it is more reliable at higher return periods. The estimated storm depths for the Project area are shown in Table 24.9.

**Table 24.9 Estimated Storm Depths for Mangaziesky Site**

| Return Period (year) | Estimated 24 hour Extreme Rainfall Depths (mm) | | | |
|---|---|---|---|---|
| | Weibull | Cunnane | Gringorton | Hazen |
| 2 | 28.46 | 28.40 | 28.39 | 28.38 |
| 5 | 40.66 | 39.87 | 39.77 | 39.63 |
| 10 | 48.74 | 47.46 | 47.31 | 47.07 |
| 20 | 56.48 | 54.75 | 54.54 | 54.21 |
| 50 | 66.51 | 64.17 | 63.90 | 63.46 |
| 100 | 74.02 | 71.24 | 70.91 | 70.39 |
| 200 | 81.51 | 78.28 | 77.90 | 77.29 |
| 500 | 91.38 | 87.57 | 87.11 | 86.39 |
| 1000 | 98.85 | 94.59 | 94.08 | 93.28 |

### *Estimation of Surface Runoff into the Open Pits*

Because the proposed pit will be located fully in the permafrost, surface water will be the main source of inflows into the pit. SRK calculated estimates of surface water runoff for average rainfall conditions and exceptional storm events.

### Peak Runoff Estimation

Storm water runoff into the pits was estimated as: storm depths (Table 24.9) multiplied by the pit area, times a runoff coefficient, which is 0.8 for all pit phases, except Phase 3. A higher runoff coefficient of 0.9 was used for Phase 3 because of pit steepening, rather than lateral extension, during this phase. The estimated daily runoff volumes are shown in Table 24.10.

**Table 24.10 Estimated Peak Flow from Storm Events for Five Defined Return Periods**

| Daily Peak Volumes Estimates ($m^3$/day) | | | | | |
|---|---|---|---|---|---|
| Return Period T = | 5 years | 10 years | 20 Years | 50 Years | 100 Years |
| Rainfall (mm/day) | 39.9 | 47.5 | 54.8 | 64.2 | 71.2 |
| Pit Stage 1 (area: 49,453 $m^2$) | 1,577 | 1,878 | 2,166 | 2,539 | 2,818 |
| Pit Stage 2 (area: 74,514 $m^2$) | 2,377 | 2,829 | 3,264 | 3,825 | 4,247 |
| Pit Stage 3 (area: 74,514 $m^2$) | 2,674 | 3,183 | 3,672 | 4,303 | 4,778 |
| Pit Stage 4 (area: 19,763 $m^2$) | 630 | 750 | 866 | 1,015 | 1,126 |

## *Hydrology and Groundwater Analysis*

### *Analysis of Permafrost*

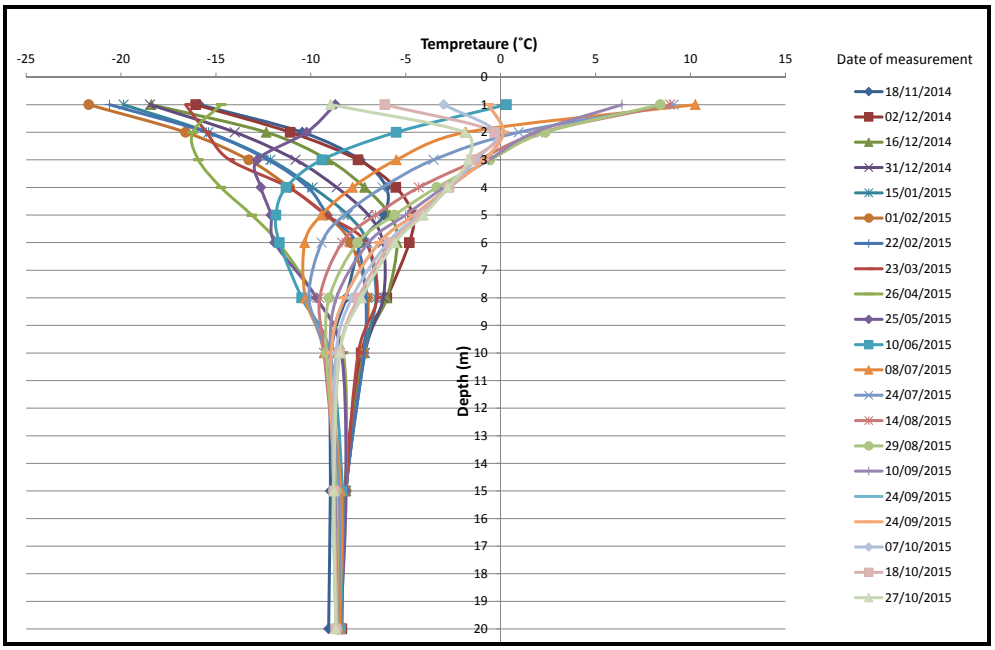
As mentioned in the previous sections, thermistors were permanently installed in two shallow boreholes (T-005 and T-006, both 30 m deep), and three deep boreholes (G-1, VG-2, and GS15-05,) in order to monitor temperature of the geological formations at various depths.

### Estimation of the Active Layer Thickness

The active layer is the top horizon of the geological formations where the temperature level during the warm season reaches the thawing point (0°C). Year-around measurements of temperature profiles were only collected from two boreholes (T-005 and T-006). The temperature profiles obtained from thermistors in borehole T-006 are shown in Figure 24.6, as an example. Data from the two boreholes were used to estimate the thickness of the active layer in the Project area.

The temperature profiles from both boreholes indicate that the maximum thawing thickness of 2.75 m is reached in late August in borehole T-006, whilst the maximum thawing thickness of 1.75 m was reached in borehole T-005.

**Figure 24.6 Temperature Profiles in Borehole T006**




## Permafrost Thickness in Deep Borehole Locations

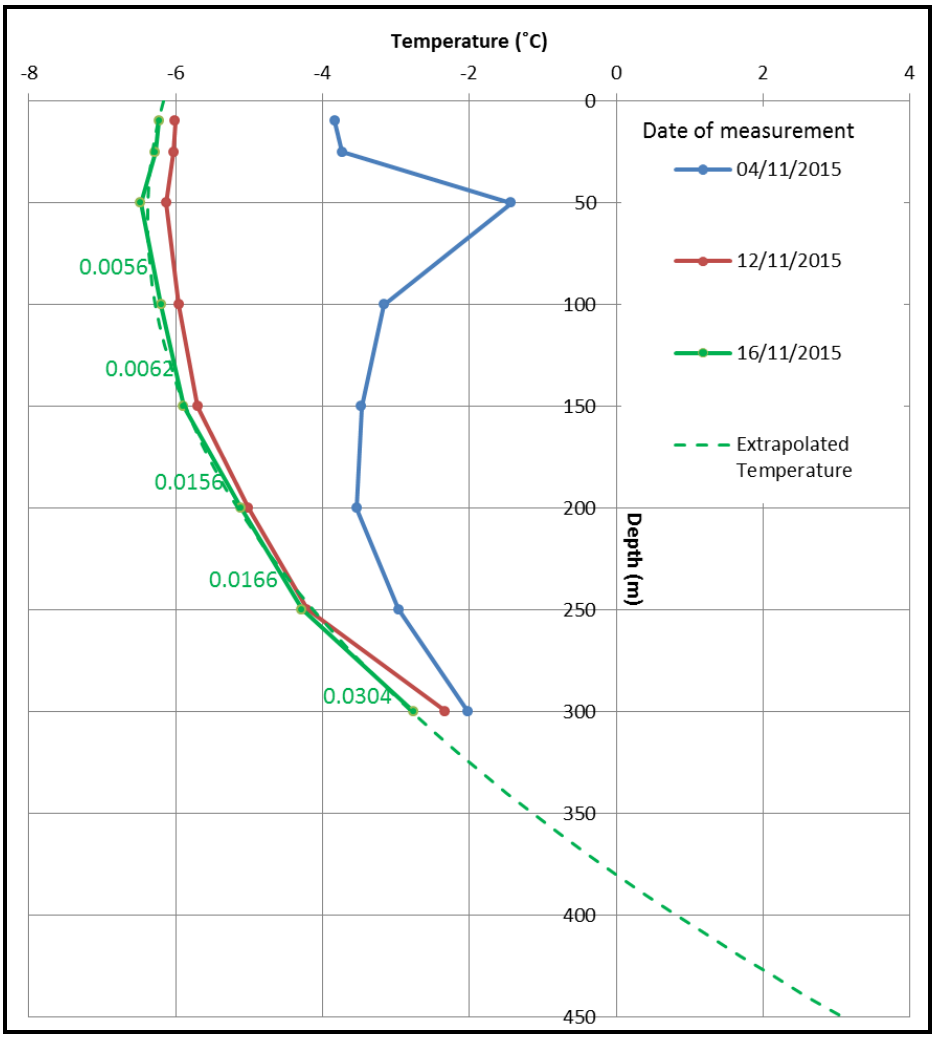
The deepest (300 m) hydrogeological borehole in the Verticalny deposit (VG-2) was intended to investigate if the underground mine will be located fully in the permafrost or if some parts of it will intersect the underlying aquifer. Thermistors were installed in borehole G-1 down to a vertical depth of 86 m. The depths of the permafrost bottom in boreholes VG-2 and G-1, which did not traverse the full thickness of the permafrost, have been estimated from the geothermal gradient obtained from the temperature measurements. An example of geothermal gradient estimation from the measured geothermal profiles and interpolation of the permafrost bottom depth is shown for borehole VG-2 in Figure 24.7.

The depth of the bottom of the permafrost layer in the four boreholes in the river valley, which reached the underlying aquifer, was estimated from drilling observations, as reported by the contractor, and geophysical survey of the boreholes. Table 24.11 shows the estimated depth of the bottom of the permafrost in all six hydrogeological boreholes. As expected the permafrost is thinner along the river valley and gets thicker toward the highland around the orebody.

**Table 24.11 Borehole Coordinates and Depth of Permafrost**

| Borehole ID | Easting | Northing | Collar Elevation RL | Depth to Bottom of Permafrost (m) |
|---|---|---|---|---|
| G-1 | 550513.071 | 7284597.004 | 1,181.757 | 400 |
| VG-2 | 551069.466 | 7283952.311 | 1,153.468 | 380 |
| GS15-01 | 551087.107 | 7286148.452 | 884.061 | 191 |
| GS15-04 | 551029.585 | 7286174.666 | 885.598 | 157 |
| GS15-05 | 553008.593 | 7283704.628 | 847.476 | 189 |
| GS15-06 | 552243.048 | 7285028.786 | 873.085 | 220 |

**Figure 24.7 Geothermal Gradient and Interpolation of the Permafrost Bottom Depth in Borehole VG-2**



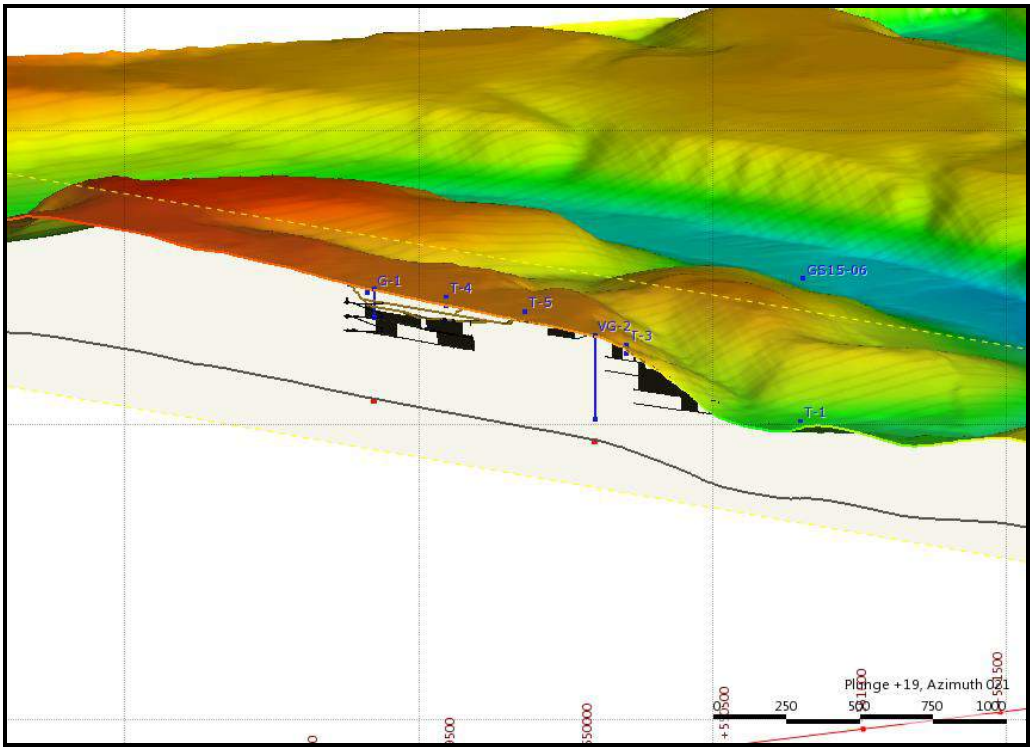

## Interpolation of the Permafrost Bottom Surface

The permafrost data analysis revealed the existence of a significant correlation between the topographic elevation and the elevation of the bottom of the permafrost layer. Therefore, the spatial variation of the bottom of the permafrost (3D surface) was constructed using linear regression interpolation, based on such correlation in boreholes GS15-01, GS15-05, GS15-06, VG-2 and G-1, and topographic data. The interpolated surface of the bottom of the permafrost shows that the thickness of the permafrost ranges between 160 m in Sirelendge River valleys and 510 m in the mountain range.

The cross section in Figure 24.8 illustrates the position of the proposed underground mine workings with respect to the bottom of the permafrost. The red dots along the vertical borehole positions represent the estimated/measured bottom of the permafrost at the borehole position, whilst the black line joining such dots shows the inferred bottom surface of the permafrost (interface between the permafrost and sub-permafrost aquifer). The proposed underground mine is shown in dark black polygons and polylines. The cross section shows that the proposed underground

mine will be located fully within the permafrost, well above the sub-permafrost aquifer.

**Figure 24.8 Cross-section along Boreholes G-1 and VG-2 Showing Position of the Permafrost Bottom in Respect to the Underground Mine (Black)**




### *Conceptual Hydrogeological Model of the Sub-Permafrost Aquifer*

Considering the significant thickness of the permafrost in the Verticalny deposit, and according to borehole cores, the sub-permafrost aquifer is located far beneath the weathered rock horizon, and groundwater flow seem driven by geological structures, mainly tectonic faults and fracture networks. This is further confirmed by the difference in the achieved borehole yield observed in the tested boreholes.

The artesian condition observed in all boreholes in the Sirelendge River valley confirms the confining property of the permafrost layer, which isolates the aquifer from surface waters. Recharge of the sub-permafrost is expected to occur during the warm season along post-permafrost faults. The aquifer recharge zones have not been identified during the site investigation. The artesian hydraulic head varies between 14 m in the downstream hole (GS15-05), and 1.1 m in the most upstream hole (GS15-04). The hydraulic head in the intermediate hole GS15-06 is 7 m above ground level. Such distribution of the artesian groundwater level may be a sign that a source of the aquifer recharge is located at a short distance upstream of borehole GS15-04.

### *Groundwater Level Map and Flow Direction*

Groundwater level (hydraulic head) data are available from the four boreholes along the Sirelendge River valley, which reached the sub-permafrost aquifer. The measured and inferred water levels (hydraulic heads) in the four boreholes are shown in Table

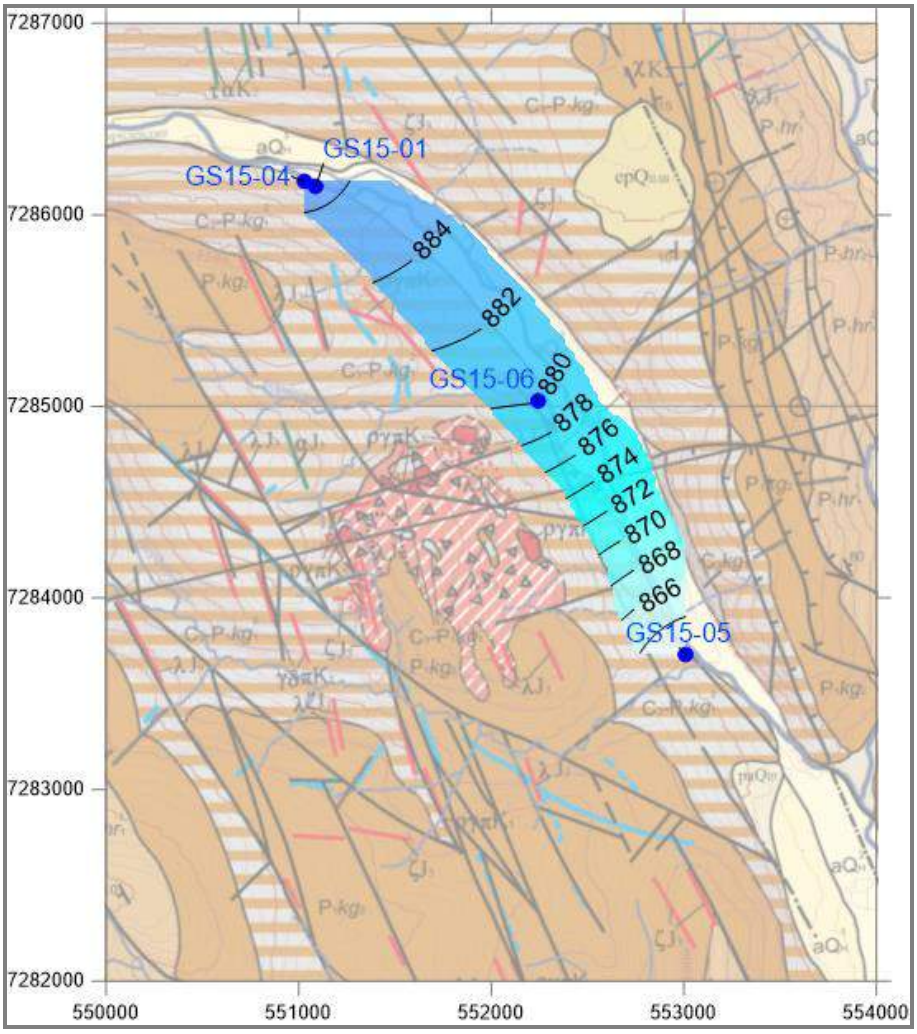
24.12. These data are used to create groundwater level contours along the Sirelendge river valley to illustrate the natural groundwater flow direction (Figure 24.9).

It is important to notice, however, that the magnitude of hydraulic gradient can also be affected by seasonal variation of water levels: measurements in boreholes GS15-01 and GS-04 were taken in June 2015 (under warm weather conditions) whilst the measurements in boreholes GS15-05 and GS15-06 were taken in November 2015 (freezing conditions).

**Table 24.12 Measured and Inferred Groundwater Levels in the Boreholes**

| Borehole ID | X | Y | Collar Elevation (mamsl) | Measured Head (mamsll) | Head Above Ground (m) |
|---|---|---|---|---|---|
| GS15-01 | 551087.1 | 7286148 | 884.06 | 886.46 | 2.4 |
| GS15-04 | 551029.6 | 7286175 | 885.5 | 886.6 | 1.1 |
| GS15-05 | 553008.6 | 7283705 | 847.84 | 861.84 | 14 |
| GS15-06 | 552243 | 7285029 | 873.08 | 880.08 | 7 |

**Figure 24.9 Groundwater Level Spatial Distribution (Contour Levels in mamsl)**



### *Analysis of Pumping Tests and Estimation of Aquifer Parameters*

Data collected from the hydraulic tests in the four boreholes along the Sirelendge River valley were analysed using the professional software AQTESOLV. The results of the data analysis are summarised in Table 24.14.

The estimated hydraulic conductivity of the sub-permafrost aquifer at borehole GS15-05 is one order of magnitude higher than that at hole GS15-06. The conductivity at the most up-gradient boreholes GS15-01 and GS15-04 is approximately four times that of borehole GS15-06. This is likely due to the fact that borehole GS15-06 is located in an intrusive formation with the absence of fault, as opposed to borehole GS15-05, which seems to be located near a fault zone, according to the background geological map in Figure 24.9. The analysis of the data provides some estimate of storage coefficient of the aquifer; however, it is known that data from the pumping well alone can result in erroneous storage coefficient estimates and therefore the values obtained from these tests should be used carefully.

### *Borehole Water Quality*

Water chemistry was obtained from laboratory analysis of water samples collected from four boreholes in the Project area (GS15-01, GS15-04, GS15-05 and GS15-06). The water quality data are compared with the international guidelines set out by the World Health Organisation (WHO 2011) for drinking water quality (Table 24.13). The comparison is for indicative purposes only and does not infer any judgement on the suitability of water for long-term usage, human or animal consumption, or for discharge to the environment.

**Table 24.13 Borehole Groundwater Quality Data**

| Parameter | Unit | Russian MPC | WHO MPC (2011) | GS15-01 | GS15-04 | GS15-05 | GS15-06 |
|---|---|---|---|---|---|---|---|
| Odour | points | 2 | | 3 | 3 | 2 | 2 |
| Taste | points | 2 | | 0 | 0 | 0 | 0 |
| Colour | degrees | 20 | | 15 | 5 | <5 | 27 |
| Turbidity | mg/L | 2.6 | | 4.9 | 2.4 | 0.4 | 4.7 |
| pH | Unit, pH | 6-9 | 6.5 - 8.5* | 7.5 | 7.5 | 7.3 | 7.5 |
| Oxidability | mg/L | 5 | | 1.1 | 1.3 | 1.7-0.3 | 2.7 |
| Nitrates | mg/L | 50 | 50 | <0.1 | <0.1 | <0.1 | <0.1 |
| Total hardness | mg-eq/L | 7 | | 14 | 11 | 4.8 | 4.3 |
| Solid residue | mg/L | 1,000 | | 1,429 | 1,200 | 1,181 | 2,277 |
| Chlorides | mg/L | 250* | 250* | 714† | 8.5 | 278† | 203 |
| Sulphates | mg/L | 500 | 250* | 12 | 10 | <10 | <10 |
| Total Iron | mg/L | 0.3 | 0.3* | 0.8† | 0.4† | 1.2† | 0.71† |
| Copper | mg/L | 1 | | <0.002 | <0.002 | <0.002 | <0.002 |
| Zinc | mg/L | 5 | | <0.005 | <0.005 | <0.005 | <0.005 |
| Arsenic | mg/L | 0.01 | 0.01 | <0.01 | <0.01 | <0.01 | <0.01 |
| Lead | mg/L | 0.01 | 0.01 | <0.006 | <0.006 | <0.006 | <0.006 |
| Fluorine | mg/L | 1.5 | | <0.04 | <0.04 | <0.04 | <0.04 |
| Cadmium | mg/L | 0.003 | 0.003 | <0.0005 | <0.0005 | <0.0005 | <0.0005 |
| Beryllium | mg/L | 0.0002 | | <0.0001 | <0.0001 | <0.0001 | <0.0001 |

*table continues...*

| Parameter | Unit | Russian MPC | WHO MPC (2011) | GS15-01 | GS15-04 | GS15-05 | GS15-06 |
|---|---|---|---|---|---|---|---|
| Boron | mg/L | 2.4 | 2.4 | <0.05 | <0.05 | <0.05 | <0.05 |
| Mercury | mg/L | 0.006 | 0.006 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Molybdenum | mg/L | 0.25 | - | <0.025 | <0.025 | <0.025 | <0.025 |
| Manganese | mg/L | 0.1 | 0.4* | <0.005 | <0.005 | <0.005 | <0.005 |
| Hydrocarbons | mg/L | 0.3 | - | 0.6 | 0.9 | - | - |
| Benzopyrene | µg/L | 0.005 | - | <0.002 | <0.002 | <0.002 | <0.002 |
| Gross α-activity | Bq/L | 0.2 | - | 0.053 | 0.046 | - | - |
| Gross β-activity | Bq/L | 1 | - | 0.11 | 0.11 | - | - |

Note: * Denotes an aesthetic/taste/odour based criterion i.e. not a health based value.
† Denotes exceedance of maximum limit allowed by WHO (2011) for drinking

It remains relevant to notice, however, that seasonal water quality variation may exist if aquifer recharge areas are located close to the borehole locations. The duration of pumping or free flow after completion of borehole drilling may also have some impact on the water chemistry. Boreholes GS15-01 and GS15-04 were sampled in June 2015, whilst the other two holes (GS15-05 and GS15-06) were sampled in November.

As shown in Table 24.13, no WHO health-based guidelines were exceeded in all four boreholes. However, iron and chloride were reported at concentrations exceeding aesthetic acceptability guidelines (criteria for taste, odour, and appearance) for drinking water. Water quality of the sampled boreholes was also compared to Russian standard (Table 24.13) MPC, since the water supply quality should comply with such regulation. Accordingly, maximum limits apply also to colour, odour, turbidity, and total hardness of water. Water from borehole GS15-01 shows exceedance of maximum limit for odour, turbidity, and total hardness, whilst GS15-04 borehole water shows exceedance for odour and total hardness, and water from borehole GS15-06 shows exceedance for colour and turbidity. The exception is borehole GS15-05 where no exceedance was observed for the additional parameters defined by Russian regulation, and therefore, only two exceedances remain valid for both WHO and Russian standards.

### *Comparison of the Investigated Water Supply Boreholes*

The water supply investigation boreholes were compared in terms of the achieved pumping yield and drawdown, the estimated aquifer parameters, and water quality. Taking into account all of the above criteria, borehole GS15-05 seems to be the most suitable site for the Project water supply, as it generally fulfils both the required water yield and quality.

**Table 24.14 Comparison of Water Supply Potential of the Boreholes**

| BH ID | Achieved Debit (L/s) | Induced Drawdown (m) | Estimated Hydraulic Conductivity* (m/d) | Estimated Storativity | Remarks on Water Quality and Exceedance of Maximum Allowed Levels | Ranking of Suitability |
|---|---|---|---|---|---|---|
| GS15-01 | 1.38 | 14.46 m (12.06m + artesian head 2.4m) | 0.26 | 0.00012 | Iron and chloride concentrations exceed the WHO aesthetic guidelines limits for drinking water.<br>It shows also exceedance of the Russian maximum limits for odour, turbidity and total hardness. | 3 |
| GS15-04 | 1.35 | 8.35 m (7.25m + artesian head 1.1m) | 0.28 | - | Iron concentration exceeds the WHO aesthetic guidelines limit for drinking water.<br>It shows also exceedance of the Russian maximum limits for odour and total hardness.<br>It has the second lowest salinity (close to that of GS15-05) | 2 |
| GS15-05 | 1.65 | 14 m (all is only Artesian head) | 0.78 | 0.00016 | Total iron and chloride concentrations exceed the WHO aesthetic guidelines limits.<br>No exceedance is found for the additional parameters defined by the Russian regulation.<br>It has the lowest salinity level despite the limited free outflow duration before freezing. | 1 |
| GS15-06 | 0.53 | 29.37 m, including artesian level (7m) | 0.07 | 1.4E-05 | Iron and chloride concentrations exceed the WHO aesthetic guidelines limits for drinking water.<br>It shows also exceedance of the Russian maximum limits for colour and turbidity. | Not suitable |

Note: *assuming aquifer thickness of 50 m

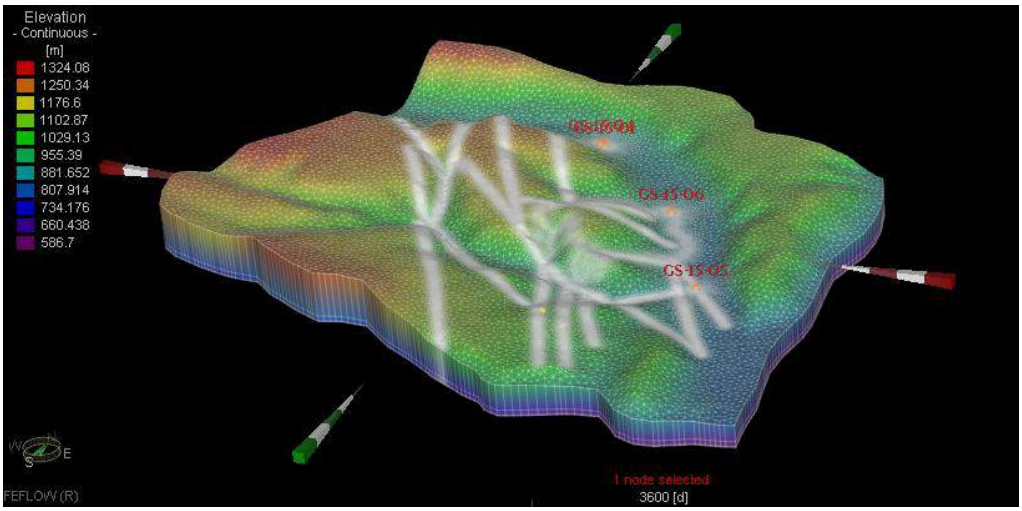
### *Groundwater Model to Simulate Pumping from Borehole GS15-05*

A numerical groundwater flow model was constructed using the finite element groundwater modelling software "Feflow" to simulate pumping from a potential water supply well at the location of borehole GS15-05. The model objective is to assess water availability and simulate the consequence of long-term pumping of groundwater from the sub-permafrost aquifer. It also compensates for the lack of long lasting pumping test that was not possible in borehole GS15-05 during the site investigation in November 2015 due to the rapid freezing of the borehole.

#### *Model Extent and Structure*

The numerical groundwater model is made up of two layers as shown in Figure 24.10. The top layer is set to be non-active to represent the impervious permafrost layer. The second layer represents the confined sub-permafrost aquifer, which is subject to the pumping simulations.

**Figure 24.10 Extent and Structure of the Groundwater Model (white lines are faults)**




The discretization of the model was made such that the elements are refined around the faults, the intrusive dykes, and the borehole locations where steep hydraulic gradient can take place during pumping. Accordingly, the size of the finite elements around the investigated boreholes was set to 0.1 m, and around the geological contact set to 10 m.

The thickness of the second layer of the model was set to 50 m, based on the conceptual understanding of the site hydrogeology. The topology of the model layer surfaces was defined according to the surface of the bottom of the permafrost that was estimated from topography and presented earlier in this report. The bottom of the aquifer follows the bottom surface of the permafrost, allowing for 50 m thickness.

#### *Model Hydraulic Boundaries and Parameters*

All model boundaries were assumed no flow boundaries and the groundwater model domain was split into three main subdomains:

- fault zones
- intrusive rock formations
- sedimentary rock formations surrounding the fault zones and intrusive rock formations.

The highest hydraulic values for the aquifer were obtained from the test at borehole GS15-05, and assigned to the fault zone. The lowest hydraulic values obtained from the test at borehole GS15-06, was assigned to the intrusive rock mass in the model. Boreholes GS15-04 and GS15-01 were drilled within a sedimentary rock formation, outside the fault zones and intrusive rock mass. The hydraulic properties obtained from the tests at these boreholes were assigned to the larger model area. Similar to the hydraulic conductivity, the specific storage properties were adopted from the results of the field tests, as shown in Table 24.15.

**Table 24.15 Hydraulic Properties used for the Numerical Model Layer 2 (Sub-permafrost Aquifer)**

| Model Zone | Hydraulic Conductivity (m/d) | | | Specific Storage ($S_s$)* |
|---|---|---|---|---|
| | $K_x$ | $K_y$ | $K_z$ | |
| Intrusive Rock Mass | 0.07 | 0.07 | 0.07 | $2.80E^{-07}$ |
| Fault Zones | 0.8 | 0.8 | 0.8 | $3.20E^{-06}$ |
| Tectonically Unaffected Sedimentary Rock Formations | 0.29 | 0.29 | 0.29 | $2.40E^{-06}$ |

Note: *Storage coefficient divided by the aquifer thickness of 50m

No groundwater recharge was considered to replenish the aquifer. Such an approach is explicitly conservative to simulate a worse-case scenario, whereby all water pumped for the project water supply would be taken from the current groundwater storage in the sub-permafrost aquifer, without allowing for the renewal of such storage.

### *Model Calibration*

The numerical model was calibrated using the groundwater level observations during the shut-in test in borehole GS15-05. The model was iteratively run until it reproduced satisfactorily the hydraulic head that was observed during the test.

### *Model Simulation Scenarios*

Various water supply scenarios were simulated in the model to assess the possibility of using the sub-permafrost aquifer as a potential source of water for the Project:

- Scenario 1: Water supply pumping at a rate of 200 $m^3$/d (2.3 L/s), 8 mo/a over a 10-year period. The assumed pumping pattern of 8 mo/a is meant to reflect the annual change in climatic conditions that regulate the availability of surface water as an alternative source of water supply during four months of the year (June to September) when water in the adjacent Sirelendge River is not frozen.
- Scenario 2: Water supply pumping non-stop 12 mo/a at a rate of 200 $m^3$/d (2.3 L/s) over a 10-year period. This conservative scenario is based on the

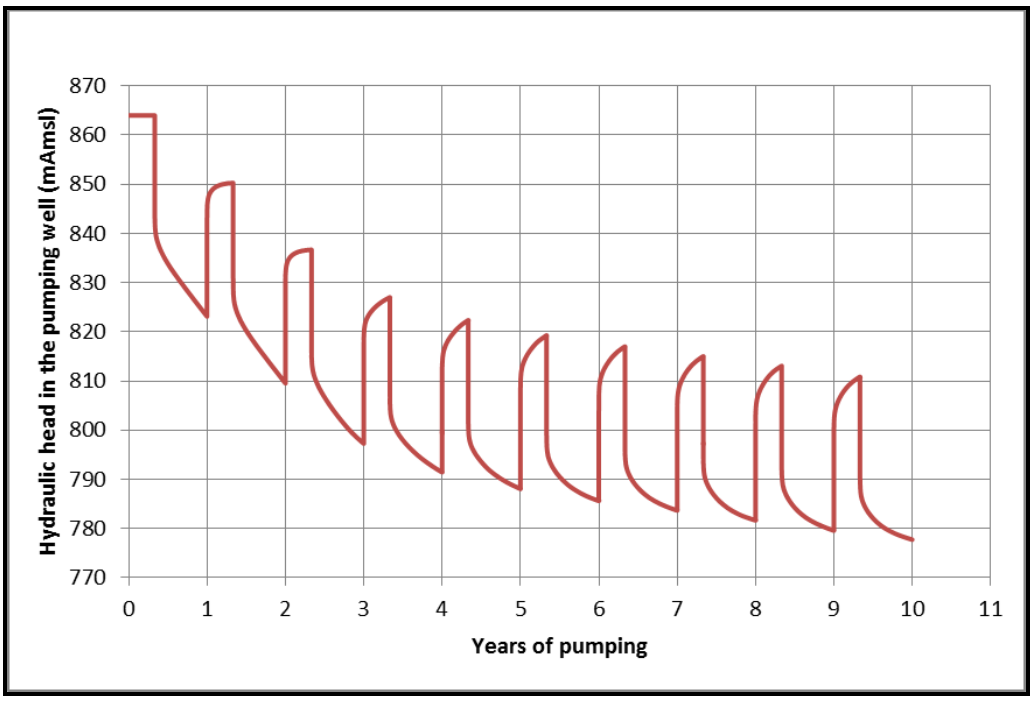
assumption that no surface water will be pumped from the river. The required amount of water supply is pumped from the borehole over the entire year.

- Scenario 3: Water supply pumping at a rate of 260 m³/d (3 L/s), 8 mo/a over a 10-year period.

### Results of Scenario 1 (Pumping 8 mo/a at a Rate of 200 m³/d)

The simulated variation in the groundwater level in the water supply well for Scenario 1 is presented in Figure 24.11. The simulated head in the pumping well at the end of the 10 year simulation period drops to 778 mamsl, which is the equivalent of a maximum drawdown of 86 m (from the initial 864 m head) in the pumping well. Comparing this drawdown to the elevation of the bottom of permafrost indicates that after 10 years of pumping from the supply well, the aquifer still remains in a confined state. The results suggest there is sufficient groundwater in the confined storage to supply the processing plant for 10 years of operations.

**Figure 24.11 Predicted Water Level in the Water Supply Well – Scenario 1**

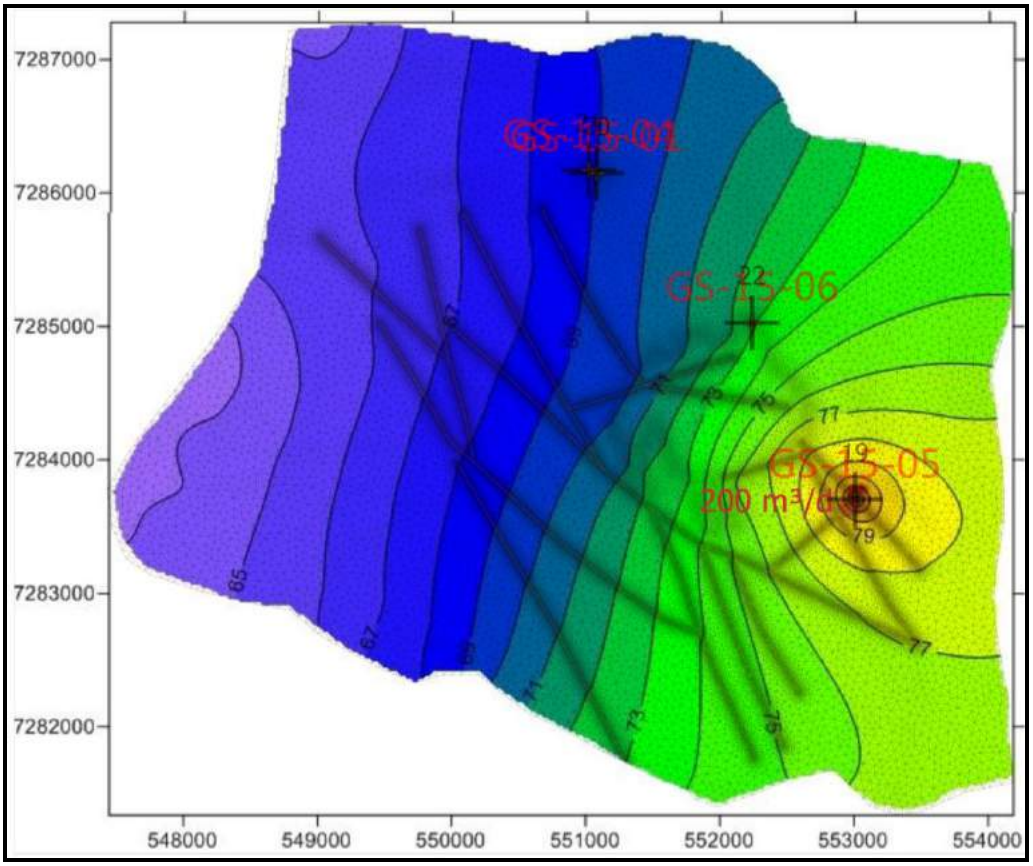



### Results of Scenario 2 (Pumping 12 mo/a at a Rate of 200 m³/d)

The groundwater model simulation results are shown in Figure 24.12 and suggest that the aquifer storage won't be depleted by pumping; however, there will be locations across the model area (outside the Project site) where the sub-permafrost aquifer may change from a confined to unconfined state. The simulated cone of depression in the pumped borehole resulting from pumping according to Scenario 2 is shown in Figure 24.13. The predicted maximum induced drawdown in the pumping well is 93 m.

**Figure 24.12 Predicted Water Level in the Water Supply Well – Scenario 2**

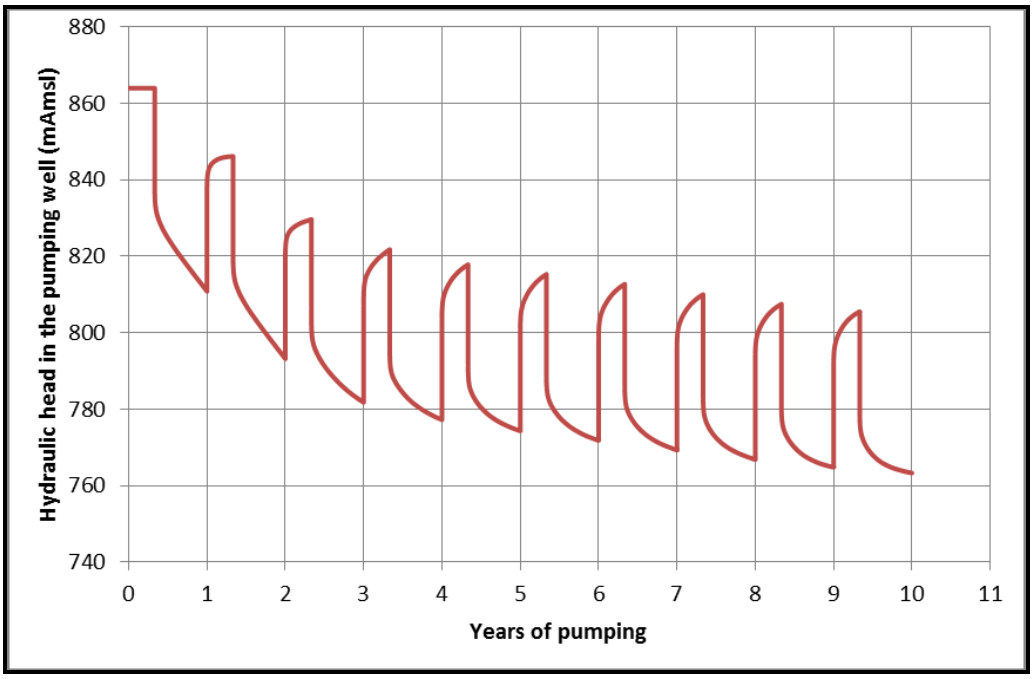
**Figure 24.13 Predicted Cone of Depression Due to Pumping – Scenario 2 (m)**



### Results of Scenario 3 (Pumping 8 mo/a at a Rate of 260 m³/d)

The predicted hydraulic head in the pumping well over time, according to Scenario 3, is shown in Figure 24.14. The model results suggest that the sub-permafrost aquifer storage will not be depleted by the end of the assumed pumping period of 10 years. The predicted maximum induced drawdown in the pumping well, according to Scenario 3 is approximately 101 m.

**Figure 24.14 Predicted Water Level in the Water Supply Well – Scenario 3**




### *Conclusions of the Groundwater Model Simulation*

The results of the two model scenarios of pumping of 200 m³/d over a 10-year period suggest the availability of enough water in the sub-permafrost aquifer to supply the Project. Increasing the required amount of water supply to 260 m³/d in the third scenario over 10 years did not result in much difference, thus indicating the availability of enough storage in the aquifer. Furthermore, a conservative approach was adopted in the model by not including any aquifer recharge, in order to simulate worst case scenario.

# 25.0 INTERPRETATIONS AND CONCLUSIONS

## 25.1 GEOLOGY

All of the exploration data for the Vertikalny, Mangazeisky North, and Nizhny Endybal deposits was reviewed and audited. In Tetra Tech's opinion, the exploration work carried out by Silver Bear has generally been completed using procedures that are consistent with recognised industry best practices, and the data is suitable for Mineral Resource estimation.

The 2015 infill drilling campaigns completed on the Vertikalny deposits provided further information in relation to the short-range variability of the grade distribution, and improved confidence in the grade continuity.

For the Mangazeisky North deposit, the parts of the deposit that were influenced by the 2015 infill drilling had sufficient data to allow the tonnage, grade, and density estimation to be completed with a suitable level of confidence for the appropriate application of technical and economic parameters, to support mine planning and evaluation of the economic viability of the deposit. This part of the deposit is therefore classified as Indicated Resource.

The Mangazeisky South deposit has sufficient data to allow the grade to be estimated, and to reasonably assume, but not verify, geological and grade continuity. Similarly, the 2011/2012 drilling at Nizhny Endybal provided adequate data to allow the grade to be interpolated, and reasonably assume, but not verify, geological and grade continuity. Both the Mangazeisky South and Nizhny Endybal Resource are classified in the Inferred category.

Tetra Tech is not aware of any material geological or resource risks associated with the Project.

## 25.2 MINERAL RESOURCE ESTIMATE

### 25.2.1 VERTIKALNY

In Tetra Tech's opinion, the established understanding of the geological and grade continuity is sufficient to support the classification of the Mineral Resources as Inferred and Indicated, as presented in this report.

In order to demonstrate that the deposit has reasonable prospects for economic extraction a cut-off grade of 200 g/t silver has been applied for resources contained within an open pit shell at Vertikalny Central or within 80 m of surface at Vertikalny Northwest. A 350 g/t silver cut-off has been applied for the underground resource, based upon the following assumptions:

- silver price of USD17.00/troy oz
- Mining cost USD2.53/t open pit and USD70.00/t underground
- Processing cost of USD52.00/t
- General and administration costs of USD40.60/t.

At Vertikalny Central, a pit shell wireframe was used to constrain the open pit resource in order to demonstrate that the resource has reasonable prospects for economic extraction. The pit shell was developed using the following assumptions:

- silver price of $19.00/troy oz
- mining recovery 95%
- waste dilution 30%
- mining cost of USD2.53/t
- processing cost of USD52.00/t
- general and administration costs of USD40.60/t
- royalty of 6.5%
- overall silver recovery of 88%.

The total Indicated Resource for the Vertikalny Central deposit is 700,000 t, with an average silver grade of 1,227 g/t. There are no Measured Resources in either the Vertikalny Central or Northwest deposits. The total Inferred Resource for the Vertikalny Central deposit is 350,000 t, with an average silver grade of 786 g/t. The total Inferred Resource for the Vertikalny Northwest deposit is 200,000 t with an average silver grade of 476 g/t. There are no Indicated Resources within the Vertikalny Northwest deposit.

### 25.2.2 Mangazeisky North/South and Nizhny Endybal

In Tetra Tech's opinion, the established understanding of the geological and grade continuity at Mangazeisky North in the areas that have been subject to infill drilling in 2015 is sufficient to support Indicate Resources. At Mangazeisky South and Nizhny Endybal the data is sufficient to support the classification of the Mineral Resources as Inferred.

In order to demonstrate that the deposits have reasonable prospects for economic extraction, a cut-off grade of 150 g/t was applied based on the following assumptions:

- forecasted silver price of $17/troy oz silver
- mining cost of $3.16/t
- processing cost of $50/t
- G&A of $12.50/t
- transport costs, from pit to process plant, of $3.60/t
- overall silver recovery of 80%.

Tetra Tech assumes that the deposits will be developed with the Vertikalny deposit, and will therefore share G&A costs.

The total Indicated Resource for the Mangazeisky North deposit is 304,000 t, with an average silver grade of 626 g/t. The total Inferred Resource for the Mangazeisky North deposit is 98,000 t, with an average silver grade of 671 g/t. The Mangazeisky South Mineral Resource is estimated at 60,000 t with an average silver grade of 246 g/t. There are no Measured Resources in either Mangazeisky North or South at this stage.

The total Inferred Resource for the Nizhny Endybal deposit is 710,000 t, with an average silver grade of 316 g/t. There are no Measured or Indicated Resources at Nizhny Endybal.

## 25.3 METALLURGICAL TESTING AND RECOVERIES

The process design for the Project was completed based on the metallurgical test work, with the objective of developing a flowsheet that is simple as possible to supply, operate, and maintain, whilst maximizing silver recovery and minimizing power requirements.

Tetra Tech analysed the metallurgical test work results with the objective of identifying the optimal process design flowsheet. The metallurgical studies confirm that the ore is amenable to gravity concentration followed by cyanidation, and can be efficiently processed using a gravity and leach based flowsheet with direct electrowinning in order to produce silver powder. The presented process plant design is based on this principle; however, allowance for the construction of additional leach tanks was made in order to process primary sulphide ore in the future.

The optimal grind size for primary grind is set at $P_{80}$ = 75 µm for oxides and $P_{80}$ = 25 µm for the primary ore type, based on the test work results.

The feasibility study process plant design is based on a 110,000 t/a capacity with a LOM average silver grade of 900 g/t, and is expected to provide a LOM silver recovery of 85% for oxide ore and 69.6% for primary ore.

## 25.4 MINERAL RESERVE ESTIMATES

The Mineral Reserve was estimated in accordance with CIM definitions and standards. According to the CIM Definition Standards for Mineral Resources and Mineral Reserves (prepared by the CIM Standing Committee on Reserve Definitions, Adopted by CIM Council on November 27, 2010), a Mineral Reserve is the economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a prefeasibility study. A Mineral Reserve includes diluting materials and allowances for losses that may occur when the material is mined. The Mineral Reserve is inclusive of the reported Mineral Resource.

Proven and Probable Mineral Reserves for the Vertikalny deposit are presented in Table 25.1.

**Table 25.1 Vertikalny Deposit Mineral Reserve Statement – September 23rd, 2016**

| Category | Cut-off Grade (g/t Ag) | Ore (t) | Ag Grade (g/t) | Ag Metal Content (koz) |
|---|---|---|---|---|
| Probable – Open Pit | 250 | 364 | 1,209 | 14,144 |
| Probable – Underground | 450 | 458 | 569 | 8,375 |
| **Total Mineral Reserves** | - | **822** | **852** | **22,519** |

## 25.5 Mining Methods

### 25.5.1 Open Pit

The integration of the open pit and underground mine design was the main task to optimise the mine boundaries and the overall open pit stripping ratio and the mine value.

The open pit mining operation will relatively be a small but high grade operation with high strip ratio in the first two years. The selected optimal boundary is robust and no redesign may be required at slightly lower silver prices. If required the cut-off grade could be recalculated with the new economic parameters (within the acceptable change variation as per the sensitivity analyses results) and continue the operation within the designed open pits.

Accurate grade control, separate ore and waste blasting patterns, and selective ore excavation techniques in the mining operation will be the main key elements to minimise the dilution and to maintain a successful operation.

Based on the prepared open pit schedule, the first four months of the 2018 will be a critical period for the waste stripping operation where there is insufficient exposed ore for the direct delivery to the processing plant. While the stockpile will be utilised to eliminate any ore delivery issues to the crusher, however, if there be an opportunity to increase the stripping in 2017, the issue may be less critical.

The selected mining and ancillary equipment are suitable for the extraction of the orebody, waste stripping, and other earthmoving operations on site. However, during the winter harsh condition, special care will be required to assure the safety of the personnel and the mining operation.

### 25.5.2 Underground Mine

Tetra Tech recommends mechanised sub-level open stoping, with remote stope cleaning, as the safest and most productive underground mining method for the Vertikalny deposit. This method is preferred as it is particularly suited for narrow vein, steeply dipping, hard rock mineralisation geometries. The implementation of this method has become more practical with the advent of mining equipment technologies that have are compact and can be operated remotely. Mine simulations show that slightly higher dilution can be expected in in sub-level open stoping when compared to shrinkage stoping, but that this drawback is overshadowed by the benefit of lower underground unit operational costs.

All lateral development will be completed using an electrically-powered, single boom jumbo drill rig, with ventilation raises developed using a long-hole drill rig (stoping drill rig). The underground Mineral Reserve will be exploited in two distinct underground mining areas in the north and south, each with each own independent ramp access. This takes into account the stopes' proximity to surface and the open pit, and the operational flexibility provided by mining multiple deposits with a single fleet of mobile equipment. For the South Zone, adit accesses were designed for some of the sub-levels, with access from a surface road and from within the South Pit. As the underground access ramps and adits will be tied into the open pit designs, the timing of their development will be contingent on the open pit mining schedule.

## 25.6 PROJECT INFRASTRUCTURE

The Project will require the development of a number of infrastructure items. The locations of project facilities and other infrastructure items were selected to take advantage of local topography, accommodate environmental considerations, and ensure efficient and convenient operation of the mine haul fleet.

Project infrastructure will include:

- airstrip
- off-site, on-site, and service road access
- mine haul roads
- TMF
- WRD, crushed ore stockpile, and ROM pad
- camp flood protection berms
- borehole water supply and distribution system
- water treatment and distribution
- sewage collection and management
- surface water management
- process and ancillary facilities, including:
  - process plant
  - crushing facility
  - reagent storage and handling
  - facilities for administration and an assay laboratory
  - heavy and light vehicle workshops
  - fuel storage and distribution
  - explosives storage and handling
  - emergency helipad
  - camp accommodation
  - mess and laundry facilities
  - medical centre
- power supply and local distribution network

- communications infrastructure.

Due to the remoteness of the mine site, Tetra Tech has purposefully steered away from an overly complex flow sheet in favour of technology that is simple and robust.

## 25.7 ENVIRONMENTAL STUDIES, PERMITTING, AND SOCIAL OR COMMUNITY IMPACT

The Project is in the early stages of the Russian review and approval process. As part of this process, the environmental and social aspects of the Project will be evaluated by the Russian regulatory authorities. There can be no guarantees that the Project will be approved under Russian law, the timeline for any decision, and if the Project is approved, that there won't be terms and conditions that will have a material impact on the feasibility of the Project.

The assessment of potential effects of the Project, the development of mitigating and management measures, and the establishment of monitoring programs embedded in the feasibility study are preliminary and are expected to evolve over time. The results of ongoing work, including ongoing environmental studies, stakeholder engagement, and permitting have the potential to influence the design, operations, and economic results of the Project.

The Project execution plan and schedule has been de-coupled from permitting activities. Construction activities are being undertaken without the necessary permits in place. Further, the commencement of mining is planned for Q4 2016 and ore processing in Q1 2017, whereas there is a high risk based on the current status that permits will also not be in place to support these operating stage activities by the dates assumed in the FS. In addition to real or perceived risks to safety and/or the environment, conducting these current and future activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material.

## 25.8 HYDROGEOLOGY AND WATER SUPPLY

As part of the Feasibility Study, site specific hydrogeological investigations have been carried out in the Verticalny deposit aiming to:

- Achieve sufficient understanding of the hydrogeology of the proposed mine and assess the dewatering requirements;
- Quantify the groundwater storage in the sub-permafrost aquifer, the availability of this to supply the required amount of water to the project.

The conclusions of the site investigations and data analysis are as follows:

- The mine (both the open pit and underground) will be located fully in the permafrost and therefore the groundwater inflow into the mine workings, if any, would be negligible.
- Surface water runoff during the warm season remains the main inflow component that requires active management, especially during exceptional

storm events. For average conditions during the warm season, the required pumping capacity to manage surface water runoff is about 100 $m^3/h$; however for exceptional storm event (100 year return period) the required pumping capacity is 200 $m^3/h$. In the freezing conditions (October to April) surface waters are frozen and precipitation falls in the form of snow, and so runoff does not occur.

- All four boreholes drilled in the Sirilendge river valley showed artesian flow, with water levels ranging from 1.1 m to 14 m above the ground level. Borehole GS15-05, which is located near the current camp, showed the highest water flow rate, indicating enough water for the project water supply. This borehole also showed the best water quality among all boreholes. Therefore, this borehole seems the most suitable for the project water supply.
- To support such observation, a numerical groundwater model was constructed and used to simulate long duration pumping from an imaginary well in GS15-05 borehole location. The model was first calibrated to reproduce the observations of the pressure recovery test that was carried out in this borehole during the investigation. Once the calibration was achieved the model was used in predictive mode to simulate various scenarios of pumping and duration. The groundwater model results suggest the existence of enough groundwater in the sub-permafrost aquifer to supply the required amount of water to the project. Nevertheless, since no long duration pumping tests were carried out as part of the Feasibility Study, the model results should be supported further with pumping tests and water quality analysis from the planned water supply wells in the spring of 2016.
- The total capital and operating cost for borehole water supply system for the project life (assumed 7 years) is estimated to around US$784,000. And the total capital and operating cost for the pit dewatering is estimated to around US$420,000 for the four years of mining.

## 25.9 CAPITAL AND OPERATING COST ESTIMATES

### 25.9.1 CAPITAL COST ESTIMATE

The total estimated initial capital cost for the design, construction, installation, and commissioning of all facilities and equipment is $49.9 million. A summary breakdown of the capital cost is provided in Table 25.2.

**Table 25.2 Capital Cost Summary**

| Area | Initial ($) | Sustaining ($) | Total ($) |
|---|---|---|---|
| Mining | 2,657,838 | 12,311,588 | 14,969,426 |
| Processing | 14,344,727 | 700,000 | 15,044,727 |
| Infrastructure | 3,717,106 | - | 3,717,106 |
| Utilities | 1,639,171 | - | 1,639,171 |
| TMF | 1,104,096 | 1,325,776 | 2,429,171 |

*Table continues...*

| Area | Initial ($) | Sustaining ($) | Total ($) |
|---|---|---|---|
| Site Facilities | 5,360,289 | - | 5,360,289 |
| Off-site Facilities | 101,454 | - | 101,454 |
| Project Indirects | 11,194,311 | 70,867 | 11,265,178 |
| EPCM | 3,525,492 | 20,248 | 3,545,740 |
| Owner's Cost | 3,850,690 | 100,000 | 3,950,690 |
| Allowances | 2,374,759 | 831,232 | 3,205,991 |
| **Total** | **49,869,933** | **15,359,711** | **65,229,644** |

Note: EPCM = engineering, procurement, and construction management

This estimate includes direct field costs required to execute the Project, plus indirect costs associated with design, construction and commissioning. This estimate is based on pricing as of Q3 2015, with no allowances for inflation or escalation. Elements of actual expenditures have been included, which further reduce the exposure to inflation or escalation. All currencies in this capital cost estimate is expressed in US dollars, unless otherwise noted.

### 25.9.2 Operating Cost Estimate

The LOM operating cost estimate for the Project consists of mining, processing, and G&A costs (which includes TMF and site water management costs) and is estimated at $158.83/t processed. Table 25.3 summarises the unit operating costs of each area.

**Table 25.3 LOM Averaged Operating Cost Summary**

| Area | Unit Cost ($/t processed) |
|---|---|
| Mining | 59.61 |
| Processing | 57.06 |
| G&A | 42.16 |
| **Total** | **158.83** |

## 25.10 Economic Analysis

An economic evaluation was prepared for the Project based on a pre-tax financial model. The base case uses a variable silver price of $19.65/oz, $18.57/oz, $19.62/oz, $19.79/oz, $19.72/oz, and $19.92/oz during Q1 2017, Q2 2017, Q3/4 2017, 2018, 2019, and 2020, as well as the remaining project life, respectively, with a LOM weighted average silver price of US$19.76/oz. The exchange rate applied in the base case is RUB66.00/USD1.00. All currency units are US dollars unless otherwise specified. For the 7.5-year LOM and 822,000 t Mineral Reserve, the following pre-tax financial parameters were calculated:

- 86.1% IRR
- 1.3-year payback on the $50 million initial capital
- $133 million NPV at a 5% discount rate.

Silver Bear commissioned PwC in Toronto, Canada, to prepare tax calculations for use in the post-tax economic evaluation of the Project with the inclusion of applicable Russian income and mining taxes. PwC estimated the applicable taxes in two cases. The first case does not account for the Far East Tax Incentives and the second case takes into account the Far East Tax Incentives (refer to Section 22.4 for further details). The following post-tax financial results were calculated for the base case without considering the Far East Tax Incentives:

- 56.1% IRR
- 1.7-year payback on the $50 million initial capital
- $83 million NPV at a 5% discount rate.

The following post-tax financial results were calculated for the base case when considering the Far East Tax Incentives:

- 81.9% IRR
- 1.3-year payback on the $50 million initial capital
- $123 million NPV at a 5% discount rate.

Sensitivity analyses were conducted to analyse the sensitivity of the Project merit measures (NPV, IRR, and payback periods) to the main inputs such as silver price, exchange rate, capital costs, and on-site operating costs. The Project's pre-tax NPV, calculated at a 5% discount rate, is most sensitive to silver price followed by exchange rate, on-site operating costs, and capital costs. The Project's pre-tax IRR is most sensitive to silver price followed by exchange rate, capital costs, and on-site operating costs. The payback period is most sensitive to silver price and exchange rate, followed by capital costs and on-site operating costs.

## 25.11 PROJECT EXECUTION PLAN

The Project is a greenfield project and will be facilitated using Owner-operated equipment and labour to mine the Vertikalny deposit.

The execution strategy for the successful monitoring and control of the Project reflects a modification to the traditional EPCM approach to project execution. Silver Bear will manage the completion of the Project with the input from various engineering companies, including a Russian-based company, who will complete the bulk of the detailed engineering, and international engineering companies, who will provide engineering review and specialist metallurgical input. Silver Bear will be responsible for the project management, procurement, and construction management using in-house resources. Short lines of decision making will be used to execute this fast-track project.

The Silver Bear execution strategy will be built on a lean, fit-for-purpose approach that favours self-sufficiency in execution and operation.

The Project site near Yakutsk will be under the direct control of Silver Bear's construction manager who will report directly to Silver Bear's CEO. Earth and civil works will be executed by Silver Bear, while contracts will be issued for structural

steel erection, mechanical and electrical installation, systems integration and specialist commissioning.

The project will reach mechanical completion in December 2016 followed by commissioning and ramp up in January 2017 to reach steady state production end of Q1 2017.

Tetra Tech concludes that the success of the project execution and future operation will rely on Silver Bear to manage the risk associated with winter road logistics. The current logistics system is sufficient for this scale of operation, and the operational team in Yakutsk has a proven track record of supporting the remote site.

# 26.0 RECOMMENDATIONS

## 26.1 GEOLOGY RECOMMENDATIONS

Tetra Tech recommends the following two phases of geology work:

- Phase 1 – infill drilling within the parts of the deposit constituting the first three years of production
- Phase 2 – infill drilling of high-grade minor parallel mineralised structures.

Advancing to Phase 2 is not contingent on the results of Phase 1.

### 26.1.1 PHASE 1 – INFILL DRILLING FIRST THREE YEARS OF PRODUCTION

Infill drilling should be considered to further improve understanding of the short range variability in the grade continuity in the areas of the deposit that will constitute the initial three years of production. These areas are confined to the open pit element of the current mine plan. The increased understanding in these areas should provide sufficient support to allow the Mineral Resources to be locally classified as Measured.

#### *PHASE 1 - DRILLING RECOMMENDATIONS*

Tetra Tech recommends a drilling campaign comprising 15 drillholes, with an approximate total length of 750 m of drilling. Figure 26.1 illustrates the proposed locations of drillholes.

**Figure 26.1 Proposed Drillhole Pierce Points**

Source: Tetra Tech

*PHASE 1 – COST ESTIMATE*

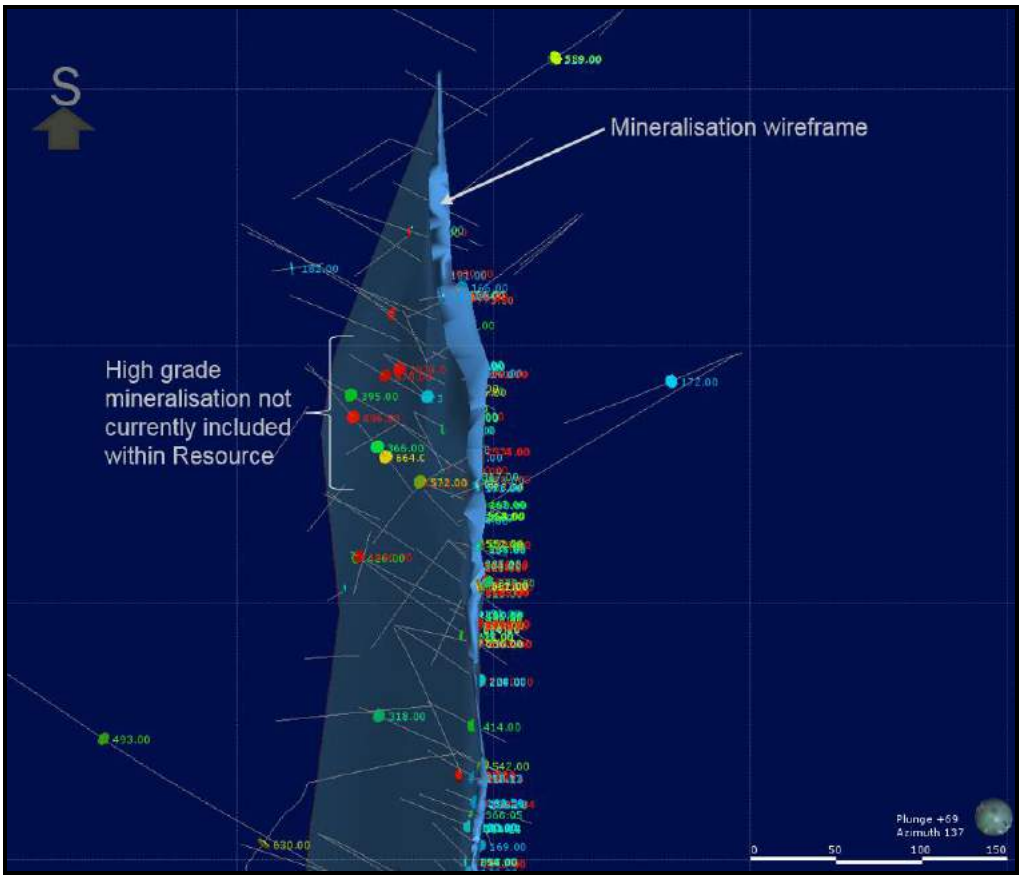
It is anticipated that the proposed drill programme will cost approximately CAD375,000 based on a drill program of 750 m, at an all-inclusive cost of CAD500/m drilled.

### 26.1.2 PHASE 2 – INFILL DRILLING HIGH GRADE MINOR PARALLEL MINERALISED STRUCTURES

The purpose of the second phase of infill drilling is to bring additional mineralisation into the Mineral Resource.

It is proposed that four additional drillholes are advanced to intersect the parallel mineralised structures that are located within the southern open pit, as defined in the mine plan. It is anticipated that the additional data will allow the structures to be modelled adequately for Mineral Resource estimation.

**Figure 26.2 3D Isometric View of the Mineralised Intercepts and Mineralisation Wireframe in the Southern Part of the Vertikalny Area**




Source: Tetra Tech

*PHASE 2 - DRILLING RECOMMENDATIONS*

Tetra Tech recommends a small drilling campaign comprising 4 drillholes, with an approximate total length of 320 m of drilling.

#### *PHASE 2 – COST ESTIMATE*

It is anticipated that the Phase 2 drill programme will cost approximately CAD160,000, based upon a drill program of 320 m, at an all-inclusive cost of CAD500/m drilled.

### 26.1.3 GENERAL GEOLOGY RECOMMENDATIONS

It is recommended that additional sulphur analysis is completed at Vertikalny to expand the dataset available for modelling oxidation state. This information should be included, with an integer classification, within the geology table of the drillhole database.

Once the additional drilling and analysis is complete, it would be advisable to develop a geo-metallurgical block model that integrates metallurgical domaining with the Mineral Resource estimation to allow refined mine planning and process optimisation.

## 26.2 MINERAL PROCESSING AND METALLURGICAL TESTING

Based on the metallurgical test work and the process plant design completed for the feasibility study, Tetra Tech recommends the following.

- Further extensive metallurgical sampling and test work on the oxide ore should be completed in order to describe the ore variability in terms of hardness and silver recovery. A better geometallurgical understanding of the ore will enable optimal and cost effective processing by way of better mine planning and scheduling.
- A QEMSCAN® mineralogical investigation and silver deportment study for the primary ore should be completed in order understand the association and liberation characteristics of silver.
- Detailed metallurgical test work for the primary ore should be completed in order to optimize the processing options and conditions. The test work should include comminution and leach optimization tests, along with intensive leach of flotation concentrates with appropriate pre-treatment.
- The processing options for primary ore should be revisited based on the outcomes of mineralogical and metallurgical studies and the size of the primary ore reserve (the feasibility study flowsheet for primary ore is not optimal, but an acceptable solution based on the understanding that the primary ore constitutes only a minor proportion of the feasibility study ore Reserves).

## 26.3 MINING METHODS

The following are recommended for the mining operation:

- The detailed topography contour map of the open pit, WRD, and the road to the crusher be prepared to be used in the detail design and scheduling phase during the mining operation.

- Adopting an accurate and practical grade control operation with standard sampling and testing protocols with short turnarounds enabling the geology and mining departments to properly plan for the short term mining schedule.
- Increase the mined material and waste striping during the warmer weather periods, allowing a relaxed operation in the winter months without any interruption in supplying the ore tonnage to the process plant.
- Local safety bylaws be adopted for the personnel and equipment operation to prevent and minimise the risk of any injury or accident in the extreme weather condition.
- Personnel and equipment fatigue be monitored on regular basis and proper remedies be considered.
- Regular alcohol and drug tests be conducted in the start of the operation at every shift to minimise the risk of accidents.
- There is still significant potentially economical mineralisation remaining post the exploitation of the underground mine plan as designed. The remaining resource can and will be further explored.
- Fully mechanised sub level open stoping requires well trained personnel. Operational readiness should be implemented six months before the start of the underground operation.

## 26.4 PROJECT INFRASTRUCTURE

Tetra Tech recommends the following for the project infrastructure:

- Equipment for the processing plant is being procured from most continents. Some areas are experiencing political instability, which may result in sanctions coming into effect. A logistics plan should be in place to re-route equipment through unrestricted regions to ensure customs clearance.
- Equipment is being manufactured on a fast-track schedule with tight delivery deadlines. Slippage of only a few weeks on some of the major items would see the winter road window closing and could result in a delay of up to 9 months until the winter road re-opens. A logistics contingency plan should be put in place to manage equipment to site should the winter road season close early, customs clearance takes longer than expected, or manufacturing schedules experience unavoidable delays.
- Equipment and material selection should be standardized by including it as a KPI for the detail design. Commonality of spares is vital for the Project to function as self-sufficiently as possible.
- A maintenance camp is set up along the winter road at a point roughly half way along, in the region of Sebyan-Kyel, to provide first aid, breakdown and accident assistance to the convoys of trucks using the winter road, as well as providing accommodation and stores for maintenance equipment.
- Fuel is tested at every step of the supply chain to monitor quality and quantity. There are reports from other mine sites in the region of fuel being sold along the route and replaced with inferior grade fuel.

- Bulk storage of ammonium nitrate for an extended period of time can result in the granules caking up, inhibiting the take up of diesel, and resulting in a less efficient ANFO mixture. It is recommended that the ammonium nitrate is screened prior to loading onto the mobile manufacturing unit to screen out the caked material.
- The winter road season is dependent on the weather conditions and, as such, cannot be predicted accurately. To allow for this, a minimum of nine months of supplies should be stored on site, with a view to increasing this capacity to at least one year of supplies in the future. A trade-off study balancing risk versus cost of storage should be conducted.

## 26.5 TAILINGS MANAGEMENT FACILITY

SRK recommends the following for the TMF:

- Methods to minimize the volumes of the surface runoff water reporting to the clarification pond should be investigated. A potential solution is the formation of a "slop cell" in the centre of the dry stack to store frozen snow. This would reduce the size of the clarification pond and the requirement for water treatment costs.
- A thermal modelling of the dry stack should be performed to verify that the dry stack will be frozen with only the top 2-m thick layer being active. This may allow a steepening of the outer slopes and reduction in the footprint of the dry stack.
- The proposed closure plan should be refined to consider progressive rehabilitation of the dry stack, which could reduce the earthworks cost estimated for the post-closure period.
- Work is being carried out by Silver Bear to establish if a government environmental waste disposal levy of $7.88/t of tails will be enforced during deposition of tailings in the TMF. This environmental charge is preliminary and could change depending on the final waste classification.
- The impact of future Russian classification and permitting of the tailings material on the design and associated cost of construction of the TMF should be considered. The TMF design has considered, where possible, the impact of local environmental, best practice, and regulatory requirements; however, at the time of publishing this study the appropriate Russian application documents and associated regulatory approvals were not available to inform the work.

## 26.6 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL OR COMMUNITY IMPACT

ERM provides the following recommendations as they relate to environmental, permitting, and regulatory aspects:

- The Project is in the early stages of the Russian review and approval process. As part of this process, the environmental and social aspects of

the Project will be evaluated by the regulatory authorities. There can be no guarantees that the Project will be approved under Russian law, the timeline for any decision, and if the Project is approved, that there won't be terms and conditions that have a material impact on the feasibility of the Project. ERM recommends that Silver Bear continue to actively engage with government authorities and community stakeholders as part of this process.

- Silver Bear has already commenced construction activities associated with the Project, in advance of obtaining all of the necessary permits. This presents procedural risks that could result in regulatory action, including fines, and re-design and/or schedule delays to the Project that could be material. ERM recommends that a detailed compliance assessment be undertaken and that Silver Bear work with regulatory authorities to address current permit gaps.
- Silver Bear has expressed its intention to comply with the Equator Principles and the IFC Performance Standards. ERM completed a gap assessment against these international frameworks for Silver Bear in November 2014 and at the time of this report an ESIA was under development. ERM recommends that Silver Bear continue efforts to align the Project with these international frameworks as a means to inform project design and the development and implementation of project-specific environmental and social management and monitoring plans. An updated gap assessment is recommended to assess the current level of alignment of the Project as defined by the feasibility study. The more advanced the Project the more difficult it may become to fill gaps remaining.
- Further engagement with local indigenous communities with regard to land and resource restoration is recommended to ensure that social requirements of the IFC Performance Standards are met.
- Further environmental studies are recommended to enhance the dataset characterizing the aquatic environment and confirm the source of elevated metals found in the local and regional waterways, including the potential impact of exploration and development activities that have already taken place. These studies should be used to inform the permitting process and to validate the effectiveness of environmental controls planned to protect the receiving environment.
- Vehicular travel adjacent to, and within the bed of the Sirelendge River and its tributaries can present a risk to water quality and fish and fish habitat and is not in accordance with good international practice for environmental protection. The current plans also present a permitting risk with Russian authorities. ERM recommends Silver Bear undertake a trade-off study and evaluate the potential for relocation of the airstrip and re-alignment of the connecting road network.
- The current water balance developed for the Project should be expanded to include site-wide surface water sources, including contact water that collects in the seepage pond, water from the TMF, and open pit and underground mine water. This water balance should be developed to characterize both the quality and quantity of water that will be managed site wide. The current model was not used to predict water quality. The water balance should be used in conjunction with a site-wide water monitoring program to validate

model predictions and confirm that environmental mitigation measures are effective and discharge can occur in accordance with anticipated permit conditions without further treatment.

- During normal operations, the TMF will be operated as a zero discharge facility, however, further study should be undertaken to define the conditions under which discharge to the environment is possible to assess the acceptability of this discharge. The Feasibility Study does not currently include an allowance for treatment of this potential waste. Further characterization of the tailings material and the potential for ARD/ML is required. The ARD/ML work completed to date is preliminary.
- A seepage and surface runoff collection pond will be constructed down gradient of the WRD that will act as a sediment control pond allowing settling of suspended solids prior to releasing water to be released to the environment. Further study is recommended to characterize the predicted quality and quantity of this waste water to confirm the assumed acceptability of release without additional management or treatment. This study should include further characterization of the waste rock that will be generated by the project and confirm that no further mitigation is required to protect the environment during operations and closure phases. The feasibility study does not currently include an allowance for further treatment of seepage that is released from this pond.
- The establishment of more detailed management and monitoring programs to validate that the project will need to be designed and implemented to support construction, operations, and closure phases of the project. Current plans are conceptual in nature. Potential costs associated with the implementation of these programs have been included as an allowance as part of the G&A costs presented in Section 21.0. ERM has not evaluated these costs and has not commented on their adequacy.
- The existing planning for closure and reclamation (as presented by others) is currently at a conceptual stage. Further planning and costing is required to support future stages of the Project and validate the assumptions made in the Study. Emphasis should be placed on defining the required technical studies needed to inform the evolution of the closure and reclamation plan over the life of the Project such that the end goals are met. Particular attention should be placed on the closure of waste facilities and the management of water post-closure, including the potential need for water treatment.

## 26.7 SITE WATER MANAGEMENT

Results of the WBM show with a greater than 95% confidence that, given the WBM's inputs and assumptions, the monthly average groundwater demand will not exceed 250 $m^3$/d during the life of the Project. This groundwater demand is approximately the amount simulated by SRK in their groundwater flow model for Scenario 3 (260 $m^3$/d). However, their groundwater flow model was calibrated to one hour of recovery from a shut-in test conducted at borehole GS15-05, which is completed in a fault. Since a pumping test could not be conducted at this borehole, we recommend hydrogeological testing be conducted at this borehole and/or at new boreholes to reduce the risk of not having a reliable water supply for the Project.

# 27.0 REFERENCES

## 27.1 MINERAL PROCESSING AND METALLURGICAL TEST WORK

Electrometals USA LLC (2014). Bench Scale Lab Test Silver Bear, Chita, Russia. 27th August 2014.

GINTSVETMET (2011). A Scientific Research Report on Ore Processing Metallurgical Tests for the Mangazeyskoye Deposit. Contract № 17/11. 2011.

SGS Vostok (2014). An Investigation into the Mineral Characteristics of a Feed Sample from the Mangazeisky Silver Project, Russia. Prepared for Silver Bear Resources Inc. Project 14426-001 – Final Report. 26th November 2014.

TOMS Institute, LLC (2015a). Brief Study Report: Metallurgical Study of Ore Samples from Verticalnoye Deposit. Prepared for ZAO Prognoz. Reference Number № ИЗ-150115-B/030315-1.

TOMS Institute, LLC (2015b). R&D Report: Technology Researches of Primary Ore – Verticalnoye Deposit. Prepared for ZAO Prognoz. Reference Number № R&D161115 B/2412151. 27th November 2015.

TSNIGRI (2008). Report Scientific Research "Technological Estimation of Samples of Silver-Polymetal Ores of Mengazeysky Deposit. Agreement #048. 25th April 2008.

## 27.2 GEOLOGY

Miller, E., Toro, J. & Prokopiev, A. (2002). Verkhoyansk Project, Final Report for Exxon-Mobil.

JSC Yangeologia (2000) Reserve Estimate.

MNRRF (2006). Ministry of Natural Resources of the Russian Federation Order of 11th December 2006. № 278, Classification Approval and Predicted Resources Solid Minerals', available at http://www.gkz-rf.ru/index.php?option=com_content&view=article&id=157:classtpi&catid=55:docstpi&Itemid= 77

Roscoe Postle Associates Inc. (2004). Technical Report on the Mangazeisky Silver Project, Yakutia, Russia. September 2004.

Tetra Tech (2013). NI 43-101 Technical Report on the Mangazeisky Property, February 2013.

Tetra Tech (2014). Technical Report – Preliminary Economic Assessment for the Mangazeisky Property. Document No. 1454430300-REP-R0001-01. 27 February 2014.

Tetra Tech (2015a). Technical Report and Resource Estimate of the Mangazeisky Silver Project. Document No. 1454430300-REP-R0003-01. 10 April 2015.

Tetra Tech (2015b). Technical Report and Resource Estimate on the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia, Russia. Document No. 705-1454430300-REP-R0004-01. 07th July 2015.

Tetra Tech (2016a). Technical Report and Resource Estimate on the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia, Russia. Document No. 705-1454430300-REP-R0005-01. 13th April 2016.

Tetra Tech (2016b). NI 43-101 Technical Report Feasibility Study, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation. Document No. 705-1454430300-REP-R0001-06. 9th June 2016.

Wardrop (2009a). Technical Report for the Mangazeisky Project, Republic of Sakha (Yakutia), Russian Federation. Document No. 0854430100-REP-R0001-01. 31 March 2009.

Wardrop (2009b). Technical Report for the Mangazeisky Project, Republic of Sakha, Russian Federation. Document No. 0854430100-REP-R0003-02. 18 December 2009.

Wardrop Engineering Inc. (2011). NI 43-101 Technical Report – Scoping Study for the Vertikalny Deposit, Mangazeisky Project. September 2011.

Western Services Report (2004).

## 27.3 SITE WATER MANAGEMENT

GoldSim Technology Group, 2010. GoldSim User's Guide, Version 10.5. December.

OOO ISKOM, 2015. Hydrological and Hydrochemical Research of Sirilende River and Borisovsky and Porfirovy Streams. Technical report prepared for ZAO Prognoz. 33 p.

SRK Consulting, 2016a. Hydrogeology and Water Supply Feasibility Study Report for Mangazeisky Mine Project, Yakutia, Russia. Technical report prepared for Silver Bear Resources Inc. 96 p.

SRK Consulting, 2016b. Mangazeisky Feasibility Study - Mining. Technical report prepared for Silver Bear Resources Inc. 158 p.

## 27.4 ENVIRONMENTAL

ERM (2016a). Assessment of Acid Potential and Geomechical Properties of Waste Rock and Tailings at the Vertikalnoye Deposit. January 2016.

ERM (2016b). Technical Report on Engineering-ecological Surveys for the Project for Construction of Ore Mining and Processing Complex on the Resource of Vertikalnoye Mining Site.

ERM (2015). Socioeconomic baseline of the Project Area. The Construction of mining and processing complex on the resource of Vertikalnoye deposit. August, 2015.

NSI (2016). Report on Assessment of possibility to use ground water as a source of water supply for the Mining and Processing Complex based on the resource of Vertikalnoye deposit. August, 2016.

(http://www.birdlife.org/datazone/sitefactsheet.php?id=16606).

# 26.0 RECOMMENDATIONS

## 26.1 GEOLOGY RECOMMENDATIONS

Tetra Tech recommends the following two phases of geology work:

- Phase 1 – infill drilling within the parts of the deposit constituting the first three years of production
- Phase 2 – infill drilling of high-grade minor parallel mineralised structures.

Advancing to Phase 2 is not contingent on the results of Phase 1.

### 26.1.1 PHASE 1 – INFILL DRILLING FIRST THREE YEARS OF PRODUCTION

Infill drilling should be considered to further improve understanding of the short range variability in the grade continuity in the areas of the deposit that will constitute the initial three years of production. These areas are confined to the open pit element of the current mine plan. The increased understanding in these areas should provide sufficient support to allow the Mineral Resources to be locally classified as Measured.

#### *PHASE 1 - DRILLING RECOMMENDATIONS*

Tetra Tech recommends a drilling campaign comprising 15 drillholes, with an approximate total length of 750 m of drilling. Figure 26.1 illustrates the proposed locations of drillholes.

**Figure 26.1 Proposed Drillhole Pierce Points**

Source: Tetra Tech

*PHASE 1 – COST ESTIMATE*

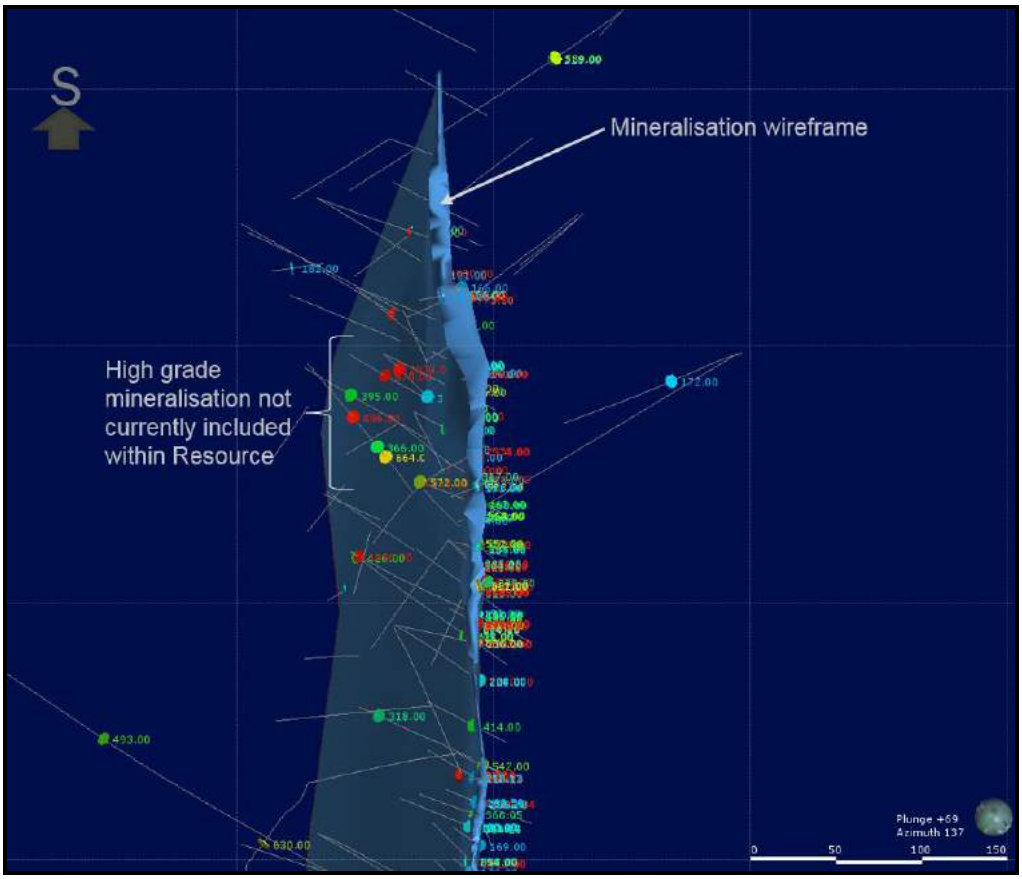
It is anticipated that the proposed drill programme will cost approximately CAD375,000 based on a drill program of 750 m, at an all-inclusive cost of CAD500/m drilled.

### 26.1.2 PHASE 2 – INFILL DRILLING HIGH GRADE MINOR PARALLEL MINERALISED STRUCTURES

The purpose of the second phase of infill drilling is to bring additional mineralisation into the Mineral Resource.

It is proposed that four additional drillholes are advanced to intersect the parallel mineralised structures that are located within the southern open pit, as defined in the mine plan. It is anticipated that the additional data will allow the structures to be modelled adequately for Mineral Resource estimation.

**Figure 26.2 3D Isometric View of the Mineralised Intercepts and Mineralisation Wireframe in the Southern Part of the Vertikalny Area**




Source: Tetra Tech

*PHASE 2 - DRILLING RECOMMENDATIONS*

Tetra Tech recommends a small drilling campaign comprising 4 drillholes, with an approximate total length of 320 m of drilling.

#### *PHASE 2 – COST ESTIMATE*

It is anticipated that the Phase 2 drill programme will cost approximately CAD160,000, based upon a drill program of 320 m, at an all-inclusive cost of CAD500/m drilled.

### 26.1.3 GENERAL GEOLOGY RECOMMENDATIONS

It is recommended that additional sulphur analysis is completed at Vertikalny to expand the dataset available for modelling oxidation state. This information should be included, with an integer classification, within the geology table of the drillhole database.

Once the additional drilling and analysis is complete, it would be advisable to develop a geo-metallurgical block model that integrates metallurgical domaining with the Mineral Resource estimation to allow refined mine planning and process optimisation.

## 26.2 MINERAL PROCESSING AND METALLURGICAL TESTING

Based on the metallurgical test work and the process plant design completed for the feasibility study, Tetra Tech recommends the following.

- Further extensive metallurgical sampling and test work on the oxide ore should be completed in order to describe the ore variability in terms of hardness and silver recovery. A better geometallurgical understanding of the ore will enable optimal and cost effective processing by way of better mine planning and scheduling.
- A QEMSCAN® mineralogical investigation and silver deportment study for the primary ore should be completed in order understand the association and liberation characteristics of silver.
- Detailed metallurgical test work for the primary ore should be completed in order to optimize the processing options and conditions. The test work should include comminution and leach optimization tests, along with intensive leach of flotation concentrates with appropriate pre-treatment.
- The processing options for primary ore should be revisited based on the outcomes of mineralogical and metallurgical studies and the size of the primary ore reserve (the feasibility study flowsheet for primary ore is not optimal, but an acceptable solution based on the understanding that the primary ore constitutes only a minor proportion of the feasibility study ore Reserves).

## 26.3 MINING METHODS

The following are recommended for the mining operation:

- The detailed topography contour map of the open pit, WRD, and the road to the crusher be prepared to be used in the detail design and scheduling phase during the mining operation.

- Adopting an accurate and practical grade control operation with standard sampling and testing protocols with short turnarounds enabling the geology and mining departments to properly plan for the short term mining schedule.
- Increase the mined material and waste striping during the warmer weather periods, allowing a relaxed operation in the winter months without any interruption in supplying the ore tonnage to the process plant.
- Local safety bylaws be adopted for the personnel and equipment operation to prevent and minimise the risk of any injury or accident in the extreme weather condition.
- Personnel and equipment fatigue be monitored on regular basis and proper remedies be considered.
- Regular alcohol and drug tests be conducted in the start of the operation at every shift to minimise the risk of accidents.
- There is still significant potentially economical mineralisation remaining post the exploitation of the underground mine plan as designed. The remaining resource can and will be further explored.
- Fully mechanised sub level open stoping requires well trained personnel. Operational readiness should be implemented six months before the start of the underground operation.

## 26.4 PROJECT INFRASTRUCTURE

Tetra Tech recommends the following for the project infrastructure:

- Equipment for the processing plant is being procured from most continents. Some areas are experiencing political instability, which may result in sanctions coming into effect. A logistics plan should be in place to re-route equipment through unrestricted regions to ensure customs clearance.
- Equipment is being manufactured on a fast-track schedule with tight delivery deadlines. Slippage of only a few weeks on some of the major items would see the winter road window closing and could result in a delay of up to 9 months until the winter road re-opens. A logistics contingency plan should be put in place to manage equipment to site should the winter road season close early, customs clearance takes longer than expected, or manufacturing schedules experience unavoidable delays.
- Equipment and material selection should be standardized by including it as a KPI for the detail design. Commonality of spares is vital for the Project to function as self-sufficiently as possible.
- A maintenance camp is set up along the winter road at a point roughly half way along, in the region of Sebyan-Kyel, to provide first aid, breakdown and accident assistance to the convoys of trucks using the winter road, as well as providing accommodation and stores for maintenance equipment.
- Fuel is tested at every step of the supply chain to monitor quality and quantity. There are reports from other mine sites in the region of fuel being sold along the route and replaced with inferior grade fuel.

- Bulk storage of ammonium nitrate for an extended period of time can result in the granules caking up, inhibiting the take up of diesel, and resulting in a less efficient ANFO mixture. It is recommended that the ammonium nitrate is screened prior to loading onto the mobile manufacturing unit to screen out the caked material.
- The winter road season is dependent on the weather conditions and, as such, cannot be predicted accurately. To allow for this, a minimum of nine months of supplies should be stored on site, with a view to increasing this capacity to at least one year of supplies in the future. A trade-off study balancing risk versus cost of storage should be conducted.

## 26.5 TAILINGS MANAGEMENT FACILITY

SRK recommends the following for the TMF:

- Methods to minimize the volumes of the surface runoff water reporting to the clarification pond should be investigated. A potential solution is the formation of a "slop cell" in the centre of the dry stack to store frozen snow. This would reduce the size of the clarification pond and the requirement for water treatment costs.
- A thermal modelling of the dry stack should be performed to verify that the dry stack will be frozen with only the top 2-m thick layer being active. This may allow a steepening of the outer slopes and reduction in the footprint of the dry stack.
- The proposed closure plan should be refined to consider progressive rehabilitation of the dry stack, which could reduce the earthworks cost estimated for the post-closure period.
- Work is being carried out by Silver Bear to establish if a government environmental waste disposal levy of $7.88/t of tails will be enforced during deposition of tailings in the TMF. This environmental charge is preliminary and could change depending on the final waste classification.
- The impact of future Russian classification and permitting of the tailings material on the design and associated cost of construction of the TMF should be considered. The TMF design has considered, where possible, the impact of local environmental, best practice, and regulatory requirements; however, at the time of publishing this study the appropriate Russian application documents and associated regulatory approvals were not available to inform the work.

## 26.6 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL OR COMMUNITY IMPACT

ERM provides the following recommendations as they relate to environmental, permitting, and regulatory aspects:

- The Project is in the early stages of the Russian review and approval process. As part of this process, the environmental and social aspects of

the Project are being evaluated by the regulatory authorities. There can be no guarantees that the Project will be approved under Russian law, the timeline for any decision, and if the Project is approved, that there won't be terms and conditions that have a material impact on the feasibility of the Project. ERM recommends that Silver Bear continue to actively engage with government authorities and community stakeholders as part of this process.

- ERM notes that the Project execution plan and schedule has been de-coupled from permitting activities. Construction activities are being undertaken without the necessary permits in place. Further, the commencement of mining is planned for Q4 2016 and ore processing in Q1 2017, whereas there is a high risk based on the current status that permits will also not be in place to support these operating stage activities by the dates assumed in the FS. In addition to real or perceived risks to safety and/or the environment, conducting these current and future activities without the necessary permits presents procedural risks that could result in regulatory action, including fines, Project re-design and/or schedule delays to the Project that could be material. ERM recommends that a detailed compliance assessment be undertaken and that Silver Bear work with regulatory authorities to address current and potential permitting/compliance gaps.
- The State Environmental Review was completed prior to the updated FS based on an optimized mine plan. ERM recommends that Silver Bear conduct a gap assessment of the FS Project and the requirements associated with the outcome of the State Environmental Review and confirm with the regulatory authorities if an amendment to the approval is required.
- Silver Bear has expressed its intention to comply with the Equator Principles and the IFC Performance Standards. ERM completed a gap assessment against these international frameworks for Silver Bear in November 2014. ERM recommends that Silver Bear continue efforts to align the Project with these international frameworks as a means to inform project design and the development and implementation of project-specific environmental and social management and monitoring plans. An updated gap assessment is recommended to assess the current level of alignment of the Project as defined by the feasibility study. The more advanced the Project the more difficult it may become to fill gaps remaining.
- Further engagement with local indigenous communities with regard to land and resource restoration is recommended to ensure that social requirements of the IFC Performance Standards are met.
- Further environmental studies are recommended to enhance the dataset characterizing the aquatic environment and confirm the source of elevated metals found in the local and regional waterways, including the potential impact of exploration and development activities that have already taken place. These studies should be used to inform the permitting process and to validate the effectiveness of environmental controls planned to protect the receiving environment.
- Vehicular travel adjacent to, and within the bed of the Sirelendge River and its tributaries can present a risk to water quality and fish and fish habitat and is not in accordance with good international practice for environmental

protection. The current plans also present a permitting risk with Russian authorities. ERM recommends Silver Bear undertake a trade-off study and evaluate the potential for relocation of the airstrip and re-alignment of the connecting road network.

- The current water balance developed for the Project should be expanded to include site-wide surface water sources, including contact water that collects in the seepage pond, water from the TMF, and open pit and underground mine water. This water balance should be developed to characterize both the quality and quantity of water that will be managed site wide. The current model was not used to predict water quality. The water balance should be used in conjunction with a site-wide water monitoring program to validate model predictions and confirm that environmental mitigation measures are effective and discharge can occur in accordance with anticipated permit conditions without further treatment.
- During normal operations, the TMF will be operated as a zero discharge facility, however, further study should be undertaken to define the conditions under which discharge to the environment is possible to assess the acceptability of this discharge. The Feasibility Study does not currently include an allowance for treatment of this potential waste. Further characterization of the tailings material and the potential for ARD/ML is required. The ARD/ML work completed to date is preliminary.
- A seepage and surface runoff collection pond will be constructed down gradient of the WRD that will act as a sediment control pond allowing settling of suspended solids prior to releasing water to be released to the environment. Further study is recommended to characterize the predicted quality and quantity of this waste water to confirm the assumed acceptability of release without additional management or treatment. This study should include further characterization of the waste rock that will be generated by the project and confirm that no further mitigation is required to protect the environment during operations and closure phases. The feasibility study does not currently include an allowance for further treatment of seepage that is released from this pond.
- The establishment of more detailed management and monitoring programs to validate that the project will need to be designed and implemented to support construction, operations, and closure phases of the project. Current plans are conceptual in nature. Potential costs associated with the implementation of these programs have been included as an allowance as part of the G&A costs presented in Section 21.0. ERM has not evaluated these costs and has not commented on their adequacy.
- The existing planning for closure and reclamation (as presented by others) is currently at a conceptual stage. Further planning and costing is required to support future stages of the Project and validate the assumptions made in the Study. Emphasis should be placed on defining the required technical studies needed to inform the evolution of the closure and reclamation plan over the life of the Project such that the end goals are met. Particular attention should be placed on infrastructure decommissioning, the closure of waste facilities and the management of water post-closure, including the potential need for water treatment.

## 26.7 SITE WATER MANAGEMENT

Results of the WBM show with a greater than 95% confidence that, given the WBM's inputs and assumptions, the monthly average groundwater demand will not exceed 250 $m^3$/d during the life of the Project. This groundwater demand is approximately the amount simulated by SRK in their groundwater flow model for Scenario 3 (260 $m^3$/d). However, their groundwater flow model was calibrated to one hour of recovery from a shut-in test conducted at borehole GS15-05, which is completed in a fault. Since a pumping test could not be conducted at this borehole, we recommend hydrogeological testing be conducted at this borehole and/or at new boreholes to reduce the risk of not having a reliable water supply for the Project.

# 27.0 REFERENCES

## 27.1 MINERAL PROCESSING AND METALLURGICAL TEST WORK

Electrometals USA LLC (2014). Bench Scale Lab Test Silver Bear, Chita, Russia. 27th August 2014.

GINTSVETMET (2011). A Scientific Research Report on Ore Processing Metallurgical Tests for the Mangazeyskoye Deposit. Contract № 17/11. 2011.

SGS Vostok (2014). An Investigation into the Mineral Characteristics of a Feed Sample from the Mangazeisky Silver Project, Russia. Prepared for Silver Bear Resources Inc. Project 14426-001 – Final Report. 26th November 2014.

TOMS Institute, LLC (2015a). Brief Study Report: Metallurgical Study of Ore Samples from Verticalnoye Deposit. Prepared for ZAO Prognoz. Reference Number № ИЗ-150115-B/030315-1.

TOMS Institute, LLC (2015b). R&D Report: Technology Researches of Primary Ore – Verticalnoye Deposit. Prepared for ZAO Prognoz. Reference Number № R&D161115 B/2412151. 27th November 2015.

TSNIGRI (2008). Report Scientific Research "Technological Estimation of Samples of Silver-Polymetal Ores of Mengazeysky Deposit. Agreement #048. 25th April 2008.

## 27.2 GEOLOGY

Miller, E., Toro, J. & Prokopiev, A. (2002). Verkhoyansk Project, Final Report for Exxon-Mobil.

JSC Yangeologia (2000) Reserve Estimate.

MNRRF (2006). Ministry of Natural Resources of the Russian Federation Order of 11th December 2006. № 278, Classification Approval and Predicted Resources Solid Minerals', available at http://www.gkz-rf.ru/index.php?option=com_content&view=article&id=157:classtpi&catid=55:docstpi&Itemid= 77

Roscoe Postle Associates Inc. (2004). Technical Report on the Mangazeisky Silver Project, Yakutia, Russia. September 2004.

Tetra Tech (2013). NI 43-101 Technical Report on the Mangazeisky Property, February 2013.

Tetra Tech (2014). Technical Report – Preliminary Economic Assessment for the Mangazeisky Property. Document No. 1454430300-REP-R0001-01. 27 February 2014.

Tetra Tech (2015a). Technical Report and Resource Estimate of the Mangazeisky Silver Project. Document No. 1454430300-REP-R0003-01. 10 April 2015.

Tetra Tech (2015b). Technical Report and Resource Estimate on the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia, Russia. Document No. 705-1454430300-REP-R0004-01. 07th July 2015.

Tetra Tech (2016a). Technical Report and Resource Estimate on the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia, Russia. Document No. 705-1454430300-REP-R0005-01. 13th April 2016.

Tetra Tech (2016b). NI 43-101 Technical Report Feasibility Study, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation. Document No. 705-1454430300-REP-R0001-06. 9th June 2016.

Wardrop (2009a). Technical Report for the Mangazeisky Project, Republic of Sakha (Yakutia), Russian Federation. Document No. 0854430100-REP-R0001-01. 31 March 2009.

Wardrop (2009b). Technical Report for the Mangazeisky Project, Republic of Sakha, Russian Federation. Document No. 0854430100-REP-R0003-02. 18 December 2009.

Wardrop Engineering Inc. (2011). NI 43-101 Technical Report – Scoping Study for the Vertikalny Deposit, Mangazeisky Project. September 2011.

Western Services Report (2004).

## 27.3 SITE WATER MANAGEMENT

GoldSim Technology Group, 2010. GoldSim User's Guide, Version 10.5. December.

OOO ISKOM, 2015. Hydrological and Hydrochemical Research of Sirilende River and Borisovsky and Porfirovy Streams. Technical report prepared for ZAO Prognoz. 33 p.

SRK Consulting, 2016a. Hydrogeology and Water Supply Feasibility Study Report for Mangazeisky Mine Project, Yakutia, Russia. Technical report prepared for Silver Bear Resources Inc. 96 p.

SRK Consulting, 2016b. Mangazeisky Feasibility Study - Mining. Technical report prepared for Silver Bear Resources Inc. 158 p.

## 27.4 ENVIRONMENTAL

ERM (2016a). Assessment of Acid Potential and Geomechical Properties of Waste Rock and Tailings at the Vertikalnoye Deposit. January 2016.

ERM (2016b). Technical Report on Engineering-ecological Surveys for the Project for Construction of Ore Mining and Processing Complex on the Resource of Vertikalnoye Mining Site.

ERM (2015). Socioeconomic baseline of the Project Area. The Construction of mining and processing complex on the resource of Vertikalnoye deposit. August, 2015.

NSI (2016). Report on Assessment of possibility to use ground water as a source of water supply for the Mining and Processing Complex based on the resource of Vertikalnoye deposit. August, 2016.

(http://www.birdlife.org/datazone/sitefactsheet.php?id=16606).

# 28.0 CERTIFICATES OF QUALIFIED PERSONS

## 28.1 JACQUES DU TOIT, CENG, PRENG, MSCENG, PMP

I, Jacques du Toit, CEng, PrEng, MScEng, PMP, of Swindon, Wiltshire, United Kingdom, do hereby certify:

- I am a Project Manager with Tetra Tech WEI Inc. with a business address at Ground Floor, Unit 2, Apple Walk, Kembrey Park, Swindon, SN2 8BL, United Kingdom.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of University of Stellenbosch, (MScEng, 2001). I am a registered Professional Engineer and a member in good standing of the Engineering Council of South Africa (20070153). I have project managed numerous feasibility studies in Africa, Russia and the CIS; all of them in base and precious metal mining. The most recent example is Kiaka Gold Feasibility Study for Volta Resources. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- My most recent personal inspection of the Property was on 21st July 2014 for one day.
- I am responsible for Sections 1.1, 1.11.1, 1.11.3, 1.13, 1.15, 1.16, 1.17, 2.0, 18.1, 18.2, 18.3, 18.5.3, 18.6, 18.7, 18.8, 18.9, 18.11, 18.13, 18.14, 18.15, 19.0, 20.7, 21.1 (except mining capital costs and tailings capital costs), 21.2.1, 21.2.2, 21.2.6, 24.1, 24.2, 25.6, 25.9, 25.11, 26.4, and 28.1 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the following reports
  - "Preliminary Economic Assessment on the Mangazeisky Silver Project, Russia" dated 27th February 2014
  - "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain

all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Swindon, United Kingdom.

*"Original document signed by Jacques du Toit, CEng, PrEng, MScEng, PMP"*

Jacques du Toit, CEng, PrEng, MScEng, PMP
Project Manager
Tetra Tech WEI Inc.

## 28.2 ROBERT DAVIES, BSC (HONS), CGEOL, EURGEOL, FGS

I, Robert Davies, BSc (Hons), CGeol, EurGeol, FGS, of Swindon, Wiltshire, United Kingdom, do hereby certify:

- I am a Senior Resource Geologist with Tetra Tech WEI Inc. with a business address at Ground Floor, Unit 2, Apple Walk, Kembrey Park, Swindon, SN2 8BL, United Kingdom.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of University of Liverpool, (BSc. Geology, 2004). I am a member in good standing and Chartered Geologist (CGeol) with the Geological Society of London (#1013629) and European Geologist (EurGeol) with the European Federation of Geologists (#965). My relevant experience includes twelve years of professional practise as a consulting geologist working in mineral exploration and resource estimation, most recently completing NI 43-101 compliant resource estimations for the Trun gold silver project in Bulgaria, the Ilovitza copper gold project in Macedonia and a JORC compliant resource estimate for the Zegen Gol, gold deposit in Eastern Russia. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- My most recent personal inspection of the Property was from the 23rd to 28th August 2015 for six days.
- I am responsible for Sections 1.2, 1.3, 1.4, 1.5, 1.7, 3.1, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 14.0, 23.0, 25.1, 25.2, 26.1, 27.2, and 28.2 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the following reports
  - "Preliminary Economic Assessment on the Mangazeisky Silver Project, Russia" dated 27th February 2014
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Yakutia Russia" dated 10th April 2015
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia Russia" dated 07th July 2015
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Mangazeisky North Deposits, Yakutia, Russia" dated 13th April 2016
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Vertikalny Deposits, Yakutia, Russia" dated 8th August 2016
  - "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.

- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Swindon, United Kingdom.

*"Original document signed by Robert Davies, BSc (Hons), CGeol, EurGeol, FGS"*

Robert Davies, BSc (Hons), CGeol, EurGeol, FGS
Senior Resource Geologist
Tetra Tech WEI Inc.

## 28.3 SABRY ABDEL HAFEZ, PHD, P.ENG.

I, Sabry Abdel Hafez, PhD, P.Eng., of Vancouver, British Columbia, Canada, do hereby certify:

- I am a Senior Mining Engineer with Tetra Tech WEI Inc. with a business address at Suite 1000, 10th Floor, 885 Dunsmuir Street, Vancouver, British Columbia, V6B 1N5.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of Assiut University (BSc Mining Engineering, 1991; MSc Mining Engineering, 1996; PhD Mineral Economics, 2000). I am a member in good standing of the Association of Professional Engineers and Geoscientists of British Columbia (#34975). My relevant experience includes more than 19 years of experience in the evaluation of mining projects, advanced financial analysis, and mine planning and optimization. My capabilities range from conventional mine planning and evaluation to the advanced simulation-based techniques that incorporate both market and geological uncertainties. I have been involved in technical studies of several base metals, gold, coal, and aggregate mining projects in Canada and abroad. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 1.14, 3.2, 22.0, 25.10, and 28.3 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Vancouver, British Columbia.

*"Original document signed and sealed by*
*Sabry Abdel Hafez, PhD, P.Eng."*

Sabry Abdel Hafez, PhD, P.Eng.
Senior Mining Engineer
Tetra Tech WEI Inc.

## 28.4 ARUNASALAM VATHAVOORAN, PHD, CENG, MIMMM

I, Arunasalam Vathavooran, PhD, CEng, MIMMM, of Swindon, Wiltshire, United Kingdom, do hereby certify:

- I am a Senior Metallurgical Engineer with Tetra Tech WEI Inc. located at Unit 2, Apple Walk, Kembrey Park, and Swindon, SN2 8BL, United Kingdom.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the University of Nottingham, United Kingdom (PhD Mineral Processing, 2006). I am a Chartered Engineer registered and in good standing of the Engineering Council (#579205), the Institute of Materials, Minerals and Mining (#444570), and the Society for Mining, Metallurgy, and Exploration (#4149245). I have practiced the profession of Metallurgical Engineering since my graduation and have been employed with Tetra Tech since 2011 as a Metallurgical Engineer, and from 2012 as a Senior Metallurgical Engineer. My relevant experience for 12 years in metallurgical engineering covers a wide range of commodities including precious metals and base metals. I have delivered detailed studies including preliminary economic assessments, prefeasibility studies and feasibility studies for mining projects located in Europe, Russia, North America, Asia and Africa.
- I have not completed a personal inspection of the Property.
- I am responsible for Section 1.6, 1.10, 13.0, 17.0, 21.2.4, 25.3, 26.2, 27.1, and 28.4 of the Technical Report.
- I am independent of Silver Bear Resources as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the following reports:
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Yakutia Russia" dated 10th April 2015
  - "Technical Report and Resource Estimate of the Mangazeisky Silver Project, Vertikalny Deposits, Yakutia, Russia" dated 8th August 2016
  - "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information and belief, the sections of the Technical Report that I am responsible for contains all of the scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Swindon, United Kingdom.

*"Original document signed by Arunasalam Vathavooran, PhD, CEng, MIMMM"*

Arunasalam Vathavooran, PhD, CEng, MIMMM
Senior Metallurgical Engineer
Tetra Tech WEI Inc.

## 28.5 ANTON FERDINAND VON WIELLIGH, B.ENG., PR.ENG., ECSA, MSAIMM

I, Anton Ferdinand von Wielligh, B.Eng. (Hons), Pr.Eng., ECSA, MSAIMM, of Perth, Western Australia do hereby certify:

- I am a Principal Mining Engineer with ABGM PTY LTD (Australia) with a business address at 5 Picotee Mews, Coogee, WA, 6166.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the University of Pretoria – South Africa, and hold a Bachelor's and Honours Degree in Mining Engineering. I am a registered Professional Engineer with the Engineering Council of South Africa (ECSA) and also a registered member with the South African Institute of Mining and Metallurgy (SAIMM). My relevant experience includes:
  - Participation as a mining engineer and as a professional engineer on various Pre-Feasibility and Feasibility studies and operating mines (in excess of 15 years study and practical experience)
  - Relevant and appropriate practical mining and mine planning experience with similar ore deposits (specifically modelled Nickel deposits) with similar structure, geometry and mineralogy.

  I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 1.8 (underground), 1.9.2, 15.0 (underground), 16.2, 16.3 (underground), 21.2.4, 25.4 (underground), 25.5.2, 26.3 (underground), and 28.5 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the following reports
  - "Preliminary Economic Assessment on the Mangazeisky Silver Project, Russia" dated 27th February 2014
  - "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Perth, Western Australia.

*"Original document signed by Anton Ferdinand von Wielligh, BEng (Hons), PrEng, ECSA, MSAIMM"*

Anton Ferdinand von Wielligh, BEng (Hons), PrEng, MSAIMM
Principal Mining Engineer
ABGM PTY LTD (Australia)

## 28.6 MAX BROWN, BSC, MSC, CENG, MIMMM

I, Max Brown, BSc, MSc, CEng, MIMMM of Bridgend, Vale of Glamorgan, United Kingdom, do hereby certify:

- I am a Principal Consultant (Geotechnical Engineering) with SRK Consulting (UK) Limited with a business address at 5th Floor, Churchill House, 17 Churchill Way, Cardiff, CF10 2HH, United Kingdom.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation", dated 4th October 2016 (the "Technical Report").
- I am a graduate of Brunel University, London, UK (BSc Geology, 1998) and the Camborne School of Mines, Cornwall, UK (MSc Mining Geology, 1999). I am a member in good standing of the Institution of Mining, Metallurgy and Materials (IOM$^3$) and a Chartered Engineer (#99300622). I have practiced my profession continuously since 2000, I have been employed by SRK Consulting (UK) Limited since February 2006 during which time I have undertaken a significant number of open pit geotechnical projects. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Section 16.1.2, 16.2.3, and 28.6 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information and belief, the sections of the Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Cardiff, United Kingdom.

*"Original document signed by Max Brown, BSc, MSc, CEng, MIMMM"*

Max Brown, BSc, MSc, CEng, MIMMM
Principal Consultant (Geotechnical Engineering)
SRK Consulting (UK) Limited

## 28.7 RENE GHARAPETIAN, P.ENG.

I, Rene Gharapetian, P.Eng., of Toronto, Ontario, Canada, do hereby certify:

- I am an Independent Mining Consultant with a business address at Tetra Tech, 6835A Century Avenue, Mississauga, Ontario.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the University of Tehran (Technical Faculty) (BSc, Mine Engineering, 1990). I am a registered Professional Engineer in good standing with the Professional Engineers of Ontario (100055424). I have practiced my profession from graduation to present. My relevant experience includes pit optimisation, open pit design, production scheduling, mine fleet estimation. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 1.8 (open pit), 1.9.1, 15.0 (open pit), 16.1, 16.3 (open pit), 21.2.3, 25.4 (open pit), 25.5.1, 26.3 (open pit), and 28.7 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- I have no prior involvement with the Property that is the subject of the Technical Report.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Mississauga, Ontario.

*"Original document signed and sealed by Rene Gharapetian, P.Eng."*

Rene Gharapetian, P.Eng.
Independent Mining Consultant

## 28.8 SAUNJAY DUGGAL, MSC, P.ENG.

I, Saunjay Duggal, MSc, P.Eng., of Mississauga, Ontario, Canada, do hereby certify:

- I am a Chief Engineer Civil/Structural with Tetra Tech WEI Inc. with a business address at 6835A Century Avenue, Mississauga, Ontario, L5N 2N2.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of National Institute of Technology, Calicut, India (Bachelor of Technology in Civil Engineering, 1992) and the University of Oklahoma, Norman, Oklahoma (Master of Science in Civil Engineering, 1996). I am a registered Professional Engineer in good standing with the Professional Engineers of Ontario (#100137875). My relevant experience includes preparation of detailed structural engineering design of buildings and appurtenances for mining facilities including preparation of associated construction documentation. Performing lead structural engineering role for feasibility study (including quantity estimate for concrete, steel and architectural items) of various mines. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 18.5.1 and 28.8 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Mississauga, Ontario.

*"Original document signed and sealed by Saunjay Duggal, MSc, P.Eng."*

Saunjay Duggal, MSc, P.Eng.
Chief Engineer Civil/Structural
Tetra Tech WEI Inc.

## 28.9 LASZLO BODI, MSC, CENG, P.ENG.

I, Laszlo Bodi, MSc, CEng, P.Eng., of Mississauga, Ontario, Canada, do hereby certify:

- I am a Principal Civil/Geotechnical Engineer with Tetra Tech WEI Inc. with a business address at 6835A Century Avenue, Mississauga, Ontario, L5N 7K2.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of Budapest University of Technology and Economics, Budapest, Hungary (B.Sc. Civil Engineering, 1977, M.Sc. Civil Engineering 1978). I am a member in good standing of the Professional Engineers of Ontario (#90235631), the Ontario Society of Professional Engineers (11386128) and the Canadian Geotechnical Society (#060398). My 37 years' experience covers a wide range of areas including detailed mining projects (waste disposal and infrastructure studies at scoping, prefeasibility and feasibility levels), foundation design and construction support for buildings, bridges, hydroelectric and nuclear power generating stations, pumping stations for TransCanada pipelines, transmission tower and pole foundations, transformer stations, large elevated storage tank and wind turbine foundations etc. I also have extensive experience in design and construction of seepage control systems (perimeter drainage and cut-off walls) around various waste disposal sites in Canada and around the World, in settlement analysis, stability analysis and design of road and railway embankments, pavement evaluations, and stability analysis and design of various concrete and earth-fill dams for mining applications. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- My personal inspection of the Property was from the 10th to 12th of August 2015, and most recently from the 11th to 13th of October 2016.
- I am responsible for Sections 18.4, 18.5.2, and 28.9 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the following reports:
  - "Preliminary Economic Assessment on the Mangazeisky Silver Project, Russia" dated 27th February 2014
  - "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain

all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Mississauga, Ontario.

*"Original document signed and sealed by Laszlo Bodi, MSc, CEng, P.Eng."*

Laszlo Bodi, MSc, CEng, P.Eng.
Principal Geotechnical Engineer
Tetra Tech WEI Inc.

## 28.10 KRYSZTOF CZAJEWSKI, BSC, P.ENG.

I, Krzysztof Czajewski, BSc, P.Eng. of Cardiff, Wales, United Kingdom, do hereby certify:

- I am a Principal Consultant (Tailings Engineering) with SRK Consulting (UK) Limited with a business address at 5th Floor, Churchill House, 17 Churchill Way, Cardiff, CF10 2HH, UK.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the University of Saskatchewan, Canada (BSc Civil Engineering, 1989). I am a member in good standing of the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC) (#131396). I have practiced my profession continuously since 1989. I have been employed by SRK Consulting since February 2007 during which time I have undertaken numerous waste disposal engineering studies for various mining operations. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Section 1.11.2, 18.10, 21.1.3 (tailings capital costs only), 21.2.5, 26.5, and 28.10 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information and belief, the sections of the Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November, 2016 at Cardiff, United Kingdom.

*"Original document signed and sealed by Krzysztof Czajewski, BSc, P.Eng."*

Krzysztof Czajewski, BSc, P.Eng.
Principal Consultant (Tailings Engineering)
SRK Consulting (UK) Limited

## 28.11 DAMIAN HICKS, MIEAUST, CPENG

I, Damian Hicks, MIEAust, CPEng, of 60 Oakfield Road, London, United Kingdom, do hereby certify:

- At the time of writing this report I was an Associate with Tetra Tech WEI Inc. with a business address at 54A Topsfield Parade, London, United Kingdom.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the University of Queensland, Australia (BEng Electrical, 2006; BSc Physics, 2006). I am a registered Chartered Professional Engineer and a member in good standing of the Engineers Australia (#2790720). My relevant experience as a chartered electrical engineer includes project experience in multiple sectors, across multiple continents. I have been involved with several international projects, with experience in producing electrical and instrumentation scope for feasibility and EPCM projects in the mineral processing sector. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 18.16, and 28.11 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November, 2016 at London, United Kingdom.

*"Original document signed by Damian Hicks, MIEAustm CPEng"*

Damian Hicks, MIEAust CPEng

## 28.12 DEREK CHRISTOPHER CHUBB, P.ENG.

I, Derek Chubb, P.Eng., of Toronto, Ontario, Canada, do hereby certify:

- I am a Senior Partner with ERM Consultants Canada Inc. with a business address at 3300 Bloor Street West, Suite 2050, West Tower, Toronto, Ontario, M8X 2X2.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of McMaster University, Hamilton, Ontario, (Bachelor of Chemical Engineering, 1990). I am a Professional Engineer and a member in good standing of the Professional Engineers of Ontario (#90328121). My relevant experience includes:
  - 24 years working in the field of environmental management
  - review and report as a consultant to numerous operations and projects on matters related to environmental and socio-economic management
  - management of the design and implementation of environmental and socioeconomic baseline data programs, regulatory submissions including EIS documents, and project permitting support
  - senior management roles with accountability for environmental affairs at several mining companies including the VP Sustainability for a company seeking to develop a project in arctic conditions (Canada)
- I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have read the definition of "qualified person" set out in National Instrument 43-101 (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 20.1, 20.2, 20.3, 20.4, 20.5, 20.6, 25.7, 26.6, 27.4, and 28.12 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Toronto, Ontario.

*"Original document signed and sealed by Derek Chubb, P.Eng."*

Derek Chubb, P.Eng.
Senior Partner
ERM Consultants Canada Inc.

## 28.13 GUY ROEMER, PE

I, Guy Roemer, PE, of Louisville, Colorado, United States, do hereby certify:

- I am an Environmental Engineer with Tetra Tech, with a business address at 363 Centennial Parkway, Suite 210, Louisville, Colorado, USA, 80027.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of Texas A&M University, College Station, Texas (BS Nuclear Engineering, 1995) and the University of New Mexico, Albuquerque, New Mexico (MS Nuclear Engineering, 1997). I am a Professional Engineer and member in good standing of the Professional Engineers of Colorado (#36810). My relevant experience includes 19 years of professional experience conducting site-wide and storage facility water balance models of mines using both spreadsheets and dynamic systems models, such as GoldSim. My experience also includes conducting groundwater flow and transport models of mine sites. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- I have not completed a personal inspection of the Property.
- I am responsible for Sections 18.12, 26.7, 27.3, and 28.13 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November, 2016 at Louisville, Colorado.

*"Original document signed by Guy Roemer, PE"*

Guy Roemer, PE
Environmental Engineer
Tetra Tech

## 28.14 HOUCYNE EL IDRYSY, PHD, CGEOL, FGS

I, Dr Houcyne El Idrysy, PhD, CGeol, FGS of Cardiff, Wales, UK, do hereby certify:

- I am a Principal Consultant (Hydrogeology) with SRK Consulting (UK) Limited with a business address at 5th Floor, Churchill House, 17 Churchill Way, Cardiff, CF10 2HH, UK.
- This certificate applies to the technical report entitled "NI 43-101 Technical Report Feasibility Study Update, Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 4th October 2016 (the "Technical Report").
- I am a graduate of the Université Libre de Bruxelles (ULB), Belgium (MSc Hydrology, 1995) and of Vrije Universiteit, Brussels (VUB), Belgium (PhD Hydrogeology, 2003). I am a Chartered Geologist and Fellow member in good standing of the Geological Society of London #1014745, and member of the International Mine Water Association (IMWA) and the International Association of Hydrogeologists. My relevant experience is in hydrogeology and mine water management. I am a "Qualified Person" for purposes of National Instrument 43-101 (the "Instrument").
- My most recent personal inspection of the Property was on 15 September 2015 for one day.
- I am responsible for Section 24.3, 25.8, and 28.14 of the Technical Report.
- I am independent of Silver Bear Resources Inc. as defined by Section 1.5 of the Instrument.
- My prior involvement with the Property was as a Qualified Person for the report titled "NI 43-101 Technical Report Feasibility Study Mangazeisky Silver Project, Republic of Sakha (Yakutia), Russian Federation" dated 9th June 2016.
- I have read the Instrument and the sections of the Technical Report that I am responsible for have been prepared in compliance with the Instrument.
- As of the date of this certificate, to the best of my knowledge, information, and belief, the sections of Technical Report that I am responsible for contain all scientific and technical information that is required to be disclosed to make the Technical Report not misleading.

Signed and dated this 16th day of November 2016 at Cardiff, United Kingdom.

*"Original document signed by Houcyne El Idrysy, PhD, CGeol, FGS"*

Houcyne El Idrysy, PhD, CGeol, FGS
Principal Consultant (Hydrogeology)
SRK Consulting (UK) Limited