REPORT

Resolution Copper Skunk Camp Pipelines

Pipeline Protection and Integrity Plan

Submitted to:

Resolution Copper

102 Magma Heights, Superior, Arizona, USA 85173

Submitted by:

Golder Associates Inc.

1575 Treat Blvd., Suite 100 Walnut Creek, California, USA 94598

+1 925 956-4800

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1.0 INTRODUCTION

Resolution Copper Mining, LLC (RCM) is proposing to develop an underground mine within the vicinity of the former Magma Copper Mine in the Pioneer Mining District near Superior, 65 miles east of Phoenix, Arizona. RCM is an LLC owned jointly by Resolution Copper Company (55%), a Rio Tinto plc subsidiary, and BHP Copper Inc. (45%), a BHP Billiton Ltd. subsidiary. Development of the project includes a panel cave mine approximately three miles east of Superior, a concentrator and associated facilities at the Concentrator Site (or West Plant Site, WPS) directly north of the town, and a tailings storage facility (TSF) connected to the concentrator by a tailings pipeline corridor.

Tailings produced at the proposed concentrator will be piped to the TSF and return water from the TSF returned to the concentrator for reuse. The design basis for the tailings pipeline corridor is a concentrator throughput of 132,000 short tons per day (stpd), as described in the Draft Environmental Impact Statement (DEIS) and Mine Plan of Operations.

The scavenger tailings and pyrite tailings will be thickened and transported separately by pipeline to the TSF. The pyrite tailings will be placed subaqueously during operations in order to manage and prevent acid rock drainage. Surplus water from the TSF will be recovered and recycled by pipeline to the concentrator for reuse in the process.

This Pipeline Protection and Integrity Plan outlines the potential failure modes and design considerations and environmental and spill control measures for pipeline construction and operation.

1.1 Climate Conditions

The regional climate is characterized as semi-arid, with long periods of little or no precipitation. Annual rainfall is between 9 and 19 inches and falls primarily during the winter and summer months, more than 50% between November and April. Temperatures frequently exceed 100°F in the summer, and occasionally dip below freezing in the winter.

2.0 PROJECT DESCRIPTION

2.1 General

The tailings will be pumped and transported as a thickened slurry in separate carbon steel, buried pipes from the Concentrator Site to the Skunk Camp TSF, located approximately 20 miles south-east following the proposed north route. Independent pipelines will be constructed for the Pyrite and Scavenger streams. A parallel return water pipeline will be installed in the same corridor to deliver reclaimed water from Skunk Camp TSF facility back to the Concentrator Site.

The pipelines will be buried and equipped with a modern control system permitting operation and monitoring of the entire system from a central control room and will include a leak detection system. The leak detection system uses process data (pressure, flow, fluid density) collected from the operating system to monitor pipeline status. Several intermediate pressure monitoring stations will be located along the pipeline at strategic locations to monitor intermediate conditions in the pipeline and support the leak detection system. The data supplements pressure, flow, and fluid density data available at the pump station and terminal station providing real-time information that supports the leak detection software system and pipeline operator decision-making.

All slurry pipelines will have intermediate facilities to support ongoing operations and monitoring of the system. These facilities will include emergency flushing tank and event pond, which will be used for extreme circumstances to prevent pipeline plugging and potentially mitigate a leak event. It is unlikely the facility will be used because there is emergency power at the pump station located at the concentrator site that can support flushing.

The pipeline Supervisory Control and Data Acquisition (SCADA) system will rely on a fiber optic cable which will be installed along the pipelines and connect remote monitoring stations to a central control room from which the pipeline operation will be monitored on a continuous basis.

All transport pipelines will include facilities to permit routine inspection with intelligent pigs to periodically assess pipeline condition. Intelligent pigs are instrumented plugs that are pumped down the pipeline to assess pipeline integrity through detection of pipeline wall loss due to corrosion and wear. This is consistent with transport pipelines designed in accordance with ASME B31.4 and with the anticipated regulatory guidelines for the proposed pipelines.

The components of the design are outlined below and described further in the following sections:

- The design basis for the tailings corridor is a concentrator average daily throughput of 132,000 stpd.
- Scavenger tails will be pumped from the tailings thickener to the TSF through a thick wall, high grade carbon steel pipeline.
- The pyrite tails will be pumped all the way to the TSF through a HDPE lined steel pipeline.
- Return water from the TSF will be pumped back to the process plant through a standard wall, carbon steel pipeline.
- The pipelines will be buried to the extent practicable.
- An access road will be constructed generally adjacent to pipelines, running along the same corridor except those areas with limited access, such as tunnel, bridge, and water crossing segments.
- Associated channels and culverts would be designed to allow passage of storm water to maintain existing upland runoff and major drainage paths that cross the corridor.
- Pipe bridges will be constructed where required to cross major drainages or washes.
- Overhead power lines will be constructed in the same vicinity generally parallel to the pipeline corridor.

2.2 Proposed Route

The tailings corridor route from the plant site to the TSF will accommodate separate pipelines for the transport of Scavenger tailings, pyrite tailings, and return water. An access road will be constructed adjacent to the pipelines and parallel overhead power lines to permit inspection of the pipeline right-of-way during operations.

The route includes a tunnel, pipeline bridges over substantial drainages or canyon, and various water and road crossings. The terrain is mountainous with a varying degree of drivability. Specific crossing designs for US Highway 60, Devil’s Canyon, Queen Creek, and the Mineral Creek have been developed and can be done using either aerial span (pipe bridge) or with trenchless crossing techniques. Bridges will be designed to span across the channel or canyon with no obstructions to ordinary high-water mark, trails, and roads and to minimize disturbance.

In general, longitudinal slopes are kept as low as practicable, bridge crossings are extended to avoid the ordinary high-water marks of major drainages and providing horizontal and vertical alignments that optimize the cut-and-fill balance as much as practicable, eliminating the need for long hauls of excavated or borrow materials. It was assumed that excavation slopes will average 1H:1V with fill slopes of 1.5H:1V.

A 500-ft wide corridor was used in the horizontal alignment. This will provide suitable distance to change the direction of or bend the selected pipes within their specified criteria. These curves allow a smooth transition of flow in select sections of the tailings pipeline.

The corridor will also include a gravel access road for inspections, maintenance, and repairs activities. Power for the tailings and recycle water systems along the corridor will be provided by solar power systems installed along the tailings corridor. Due to the low cost and maintenance requirements, solar power systems are selected to provide power for pipeline corridor facilities over multiple transformers to draw power from the parallel high voltage power transmission lines. The corridor will also include a multi-fiber optic cable for communication and instrumentation to support leak detection monitoring of the pipelines.

2.3 Drainage

Suitable drainage of the tailings corridor is essential in maintaining the integrity of this system. In general, all upland storm water runoff will be allowed to continue flowing down gradient within existing drainages via drainage culverts under the corridor. Where it is not practical to install a culvert along the alignment of an existing stream (e.g., where the corridor is in a cut), or where the discharges are small, runoff will be collected in the up gradient diversion channel and conveyed parallel to the corridor for conveyance through culverts placed at desired locations. Design of the drainage facilities and culvert sizing for major drainage paths under the corridor will need further optimizing.

2.4 Pipelines

2.4.1 Design Codes and Standards

Pipelines will be designed, manufactured, constructed, commissioned, and maintained in accordance with ASME B31.4 – Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids. The American Society of Mechanical Engineers (ASME) has been defining piping safety since 1922. Since then, the B31.4 code has become the governing code in the industry to prescribe requirements for the design, materials, construction, assembly, inspection, testing, operation, and maintenance of liquid pipeline systems between facilities (also called out-of-fence pipelines). For decades, numerous pipeline designers, owners, regulators, inspectors, and manufacturers have used B31.4 code to comply with applicable regulations within their jurisdictions.

Although tailings is not a hazardous liquid, additional applicable requirements specified in CFR Title 49 Part 195 – Transportation of Hazardous Liquids by Pipeline and will be implemented. This Part prescribes safety standards and reporting requirements for pipeline facilities used in the transportation of hazardous liquids. Primary industries served include most if not all long distance, cross country onshore pipeline systems that highly volatile liquid, transport crude oil, and other refined liquid petroleum products.

The combination of ASME and CFR represents the common practice for the design, construction, and maintenance of long distance hazardous liquid pipelines (i.e. hydrocarbon-based liquids) in United States and it certainly has a higher standard and more stringent requirements than other widely used non-hazardous liquid pipeline codes and standards (such as American Water Works Association, also called AWWA). Therefore, RCM pipelines will be designed, constructed, and maintained according to ASME and CFR, which would represent best practice in industry.

Furthermore, the pipeline systems will comply with applicable local regulations and standards, including Arizona Department of Transportation (DOT) rules. Where there is a conflict or discrepancy between any applicable codes and standards, the most stringent requirement shall apply.

Please refer to additional pipeline design codes and standards in Appendix A – Design Criteria.

2.4.2 Scavenger Tailings

The scavenger tailings pipeline is designed for 60-65% solids slurry. The slurry flow velocity is designed to exceed the expected settling velocity.

The scavenger tails will be pumped from the tailings thickener underflow through pipelines to the TSF. As the pipeline is likely to slowly erode due to some coarser particles in the slurry, a 1.25-inch (thickest pipe for pipeline construction) will be used. Pipe thicknesses will provide at least 21-year operating life based on a conservative estimate of corrosion and/or erosion potential in the pipeline. Regular intelligent pig inspection of the line will verify the rate of metal loss and may result in a longer pipe service life.

The selection of suitable pipe material for the steeper sections of the pipe will control the slurry velocity without the need for drop boxes. Controlling the velocity will help reduce the potential erosion of the pipe as well as safety screens to remove oversize material prior to entry into the pipeline. Drop boxes were eliminated as an environmental and safety improvement as presented in the original GPO to reduce the potential for leaks and eliminate wildlife and human contact with tailings as the drop boxes are open to the atmosphere. The removal of drop boxes from the design also allows for the access road to follow the same grade as the pipes, making visual inspections and maintenance easier and more effective and reduce overall disturbance.

2.4.3 Pyrite Tailings

The pyrite tailings pipeline was designed for a pumped flow of 45-50% solids. The slurry flow velocity exceeds the expected settling velocity. The pyrite tails will require pumping in series through a pipeline to the tailings impoundment. The pyrite slurry is fine particles which will not wear the steel pipe; however, the presence of pyrite creates are risk of a high corrosion rate in the line resulting in the addition of an internal HDPE liner as a corrosion barrier.

2.4.4 Return Water

The return water pipeline recycles water from the tailings and thickeners to a return water tank at the TSF site. From here, the system requires pumping to return the water to the concentrator for reuse.

2.4.5 Pipe Material

The following types of pipe are used in the design:

- Heavy Wall/High Grade Carbon Steel – The majority of pipelines for conveyance of scavenger tailings and recycle water will be comprised of heavy wall, high grade steel.
- HDPE-lined steel pipe will be used for transporting pyrite tailings to mitigate corrosion to negligible levels.

2.4.6 Pipe Installation

Except pipeline sections inside tunnel, at special crossings or facilities, open-cut installation method will be used for buried line pipe construction along the corridor. At intermittent facilities, piping will be installed above grade supported by pipe supports. The piping will be properly anchored at connections to rigid structures such as the tailings head tank. Expansion joints will be provided in cases where steel pipes need to be connected to rigid structures, as required.

2.5 Access Roads

The tailings corridor includes a gravel-surfaced access road running adjacent to the pipelines to provide access between the concentrator and the TSF. In fill areas, an earthen safety berm will be constructed alongside the road.

A wheel wash will be provided at the TSF end of the tailings corridor to ensure contact tailings material on site vehicles is removed before travelling along the corridor access road.

2.6 Tunnel

Drill-and-blast tunneling method is considered as the preferred construction method due to the relatively short-tunnel length. The tunnel cross-sectional area is nominally 15-ft wide by 15-ft tall horseshoe shaped. This tunnel size will not only provide adequate space to accommodate four operating and two replacement tailings pipelines, but also allow 24/7 access for construction and maintenance equipment.

2.7 Pipe Bridges

Pipe bridges will be constructed along the tailings corridor alignment to span major drainages outside of the ordinary high-water mark, including bridges over Queen Creek and over Devil's Canyon.

The pipe bridges would include a walkway and a vehicle access for inspections and maintenance purposes.

Steel piping on the pipe bridges will be designed to have sufficient flexibility and strength to accommodate its own expansion/contraction as well as the bridge's maximum deflection caused by the thermal expansion.

2.8 Road Crossings

The pipeline crossings at public or private roads will be designed to accommodate both the pipeline and road requirements in these areas. All pipelines at road crossings will be designed in accordance with API RP 1102.

All road crossing pipe segments of this corridor will be uncased. Uncased pipe is preferred than cased pipe due to various reasons. Recent comparative studies of scheduled or immediate responses/mile versus number of repairs from an Interstate Natural Gas Association of America (INGAA) study and the US Pipeline and Hazardous Materials Safety Administration (PHMSA) database suggests cased pipe segments are less safe than uncased segments. In addition, operational maintenance and the integrity of uncased crossings are better maintained due to not having the casing around the pipeline. Common casing pipe issues include failed casing end seals that let water and mud into the casing, or casing and spacers for the pipeline to short against partial electrolytic contact (water) and cause corrosion.

3.0 FAILURE MODES ANALYSIS

3.1 General Description

Pipelines have the potential to fail for several reasons, resulting in leaks or release of slurry. The most common causes of pipeline failure are outlined below. The prevention measures, to reduce the chance of failure, are identified in the risk assessment (Section 3.3) and further detailed in Section 4.0 of this plan.

3.1.1 Mechanical

Mechanical failures include punctures, cuts, crushing, and separation. The cause of these failures is primarily accidental impact from construction or operations equipment. A small number of mechanical failures are the result of manufacturing defects or inferior materials.

3.1.2 Operational

Operational failures include separation, collapse, accidental release, or failures related to pipe movement. An overpressure event will cause ruptures or separation at joints or equipment connections.

3.1.3 Corrosion and Erosion

Corrosion is a natural process that converts a refined metal to a different form, such as an oxide, hydroxide, or sulfate. It is the gradual destruction of metals by chemical reaction with their environment. Corrosion may be pitting, weld decay, crevice corrosion, and microbial corrosion.

Wear or abrasive erosion is defined as the gradual and progressive loss of material due to the relative motion between the pipe wall and a fluid containing solid particles. The magnitude of wear depends on the angle of impingement and the type of material being eroded.

Each of these can result in leaks and potential pipe failures if the pipeline segment is not repaired or replaced before becoming too thin.

3.1.4 Natural Hazards (Geohazards)

Natural hazards are events or processes in nature that can result in damage from ultraviolet light, rainfall, flooding, landslides and other geohazards such as seismicity, wind, lightning strikes, plants, and animals.

Geohazard assessment along the length of the pipeline corridor was completed and is contained in Appendix B.

3.1.4.1 Slope Instability

Several locations along the corridor alignment have been identified as having low to moderate potential for slope instability. All locations should be included in a slope monitoring program for the mainline, whereby site inspections are performed and measurements with geotechnical instrumentations are taken regularly to monitor slope performance.

3.1.4.2 Seismic

Common seismic risks include ground shaking, liquefaction, and surface fault rupture. The corridor alignment is located in an area of apparent low historical seismic activity and appears to have low potential for damage from future seismic activity.

The projected 475-year return period peak ground acceleration (PGA) values are low, averaging between about 0.04 g along most of the route, which is within the “low” hazard classification for seismic shaking. Ground motions at these levels are unlikely to produce structural damage to the pipeline. Conditions suitable for liquefaction are likely to be limited along the proposed pipeline alignments, due to the regionally dry climate and typically dry soil conditions for at least the first few feet of the subsurface. In addition, no active faults in the vicinity of the alignment were identified in any of the references reviewed.

3.1.4.3 Scour Potential

A number of watercourse crossings along the corridor alignment have been identified as exhibiting high potential for lateral and/or vertical scour. The integrity of the pipeline will be maintained by mitigation measures and design features to prevent this occurrence include appropriate depth of cover at watercourse crossings, crossing in non-saturated reaches, completely spanning the water course outside the OHWM (Queen Creek and Devil's Canyon) or going under the watercourse outside the OHWM (Mineral Creek).

3.1.4.4 Ground Subsidence

Potential hazards of ground subsidence have been identified across the conversion alignment, and include:

- underground mine areas near shaft 9 and 10
- potential and/or known karst areas and features near the Concentrator Site
- potential subsurface fluid withdrawal-related subsidence areas

Some areas along the alignment have been classified as having "moderate to high" potential for ground subsidence due to their close proximity to the underground mine subsidence. These areas will be further studied to observe on or in the immediate vicinity of the proposed corridor using aerial reconnaissance and will be monitored regularly during aerial patrols and ground inspections, as part of pipeline integrity management plan.

3.1.5 High Consequence Area (HCA)

This pipeline corridor has applied the concept of high consequence area (HCA) from US pipeline safety regulations (49 CFR Part 195). Due to the existence of critical habitats (such as Gila Chub), the mineral creek crossing is considered as the high consequence area.

Trenchless crossings are proposed at this location to drill below grade through state owned land and forest service land directly and will start and end outside the OHWM and critical habitat boundaries. Additionally, this area of the crossing is outside the saturated reach of Mineral Creek. Trenchless crossing is currently the preferable option to avoid disturbance of the critical habitats in the area and to mitigate the sour potential risk at this water crossing location.

3.1.6 Third-Party Damage

Third-party damage can be categorized as intentional / malicious damage, accidental damage, and incidental damage. Intentional / malicious damage would be the result of theft or intent to cause harm; historically there have been issues with people in the area shooting at objects for target practice. Accidental damage can take many forms including damage from private vehicles hitting the pipeline. Incidental damage is defined as damage to a pipeline that does not cause an immediate leak or failure but results in a failure over time.

3.2 Frequency of Failure

Historical data related to causes and frequency of failure of pipelines in Western Europe[1] were used in identifying the probability of failure. Conditions causing pipe failure under given circumstances are similar around the world, and this information on failure frequency is considered suitable for use in this analysis. It has been demonstrated that overland pipeline failures occur less than 0.01% of the time, generally as a result of third-party accidental, mechanical, and operational issues. Most of the time, 50% to 90%, these failures result in a leak size of 0.4 inches or less. Full-bore failure is usually caused by natural hazards but is the least frequent of the failures (0.001%).

3.3 Failure Modes Assessment and Mitigation Matrix

A matrix was developed for the pipelines running through the tailings corridor to align the hazard with potential failure modes with measures and design features to manage and minimize the failures during construction and operation. The matrix identifies how and where hazards and failure modes could originate and identify design features, preventive measures, and management strategies for the pipelines. The matrix is shown in Table 1. Additional pipeline design parameters, codes, and standards are included in Appendix A – Design Criteria.

Spill prevention and detection are the most important environmental aspects of the pipelines. The proposed corridor infrastructure and operational controls take these considerations into account over the entire alignment.

Best practice environmental protection measures and controls will be implemented to prevent leaks and spills from the pipelines. Preventive measures will be put in place and procedures followed throughout the life of the facility—from construction and operation. The proposed controls identified for each phase of work are outlined in the following section.

Quality assurance practices will help ensure the planned control measures are met during each phase. Equipment, materials, and the development of management plans will be in accordance with best practice design codes and standards covering the following:

- pipeline treatment and testing
- inspection procedures during fabrication
- identification of specific product parameters
- fabrication and welding control
- pipe coating inspection and testing
- valve manufacture and testing
- pipeline hydrotesting
- advanced pipeline control and monitoring system including leak detection
- routine pipeline inspection including internal intelligent pig runs to verify pipeline integrity

[1] Data source – Consideration of Clean Air Water in Western Europe Report 98: Western European Cross-Country Oil Pipelines 25 Years Performance Statistics, June 1988 and European Gas Pipeline Incident Data Group.

- routine pipeline right-of-way inspections.

Table 1: Failure Modes and Mitigation Measures Matrix for Tailings Corridor Pipelines

Category	Potential Failure Mode	Defensive Design and Operational Measures	Details in Section
Geohazards	Landfill and Rock fall / Pipe damage, spill, and shutdown	• routing adjustments to avoid unstable slopes • slope stabilization, grade, revegetation, as required • implement best management practices (BMPs) and best construction practices (BCPs) • conduct field assessments to confirm and characterize each location and its potential associated hazards • conduct routine pipeline corridor inspections	**4.2.1, 4.2.2, 4.5.4**
	Seismic – ground shaking. Liquefaction, surfaces fault rupture / pipe damage, spill, and shutdown	• use heavy wall and high-grade carbon steel pipe • optimize trench dimensions and fill materials to minimize the additional stresses, as needed • specially designed aboveground fault crossings, if necessary • conduct routine pipeline corridor inspections	**4.2.1, 4.2.2, 4.2.3, 4.5.4**
	Ground Subsidence – Karst, Underground Mine, Fluid Withdrawal / Pipe damage, spill, and shutdown	• cross several areas of low to moderate subsidence hazards • a site-specific geophysical survey be completed to approximate the extent of any subsurface voids if they exist prior to construction • implement best management practices (BMPs) and best construction practices (BCPs) • conduct routine pipeline corridor inspections	**4.2.1, 4.2.2, 4.5.4**
Hydrology and Hydrogeology	Hydrotechnical Hazards / exposed pipeline in water streams and pipe damage, spill, and shutdown	• small re-routes for an improved pipeline alignment • deeper burial and/or placement of the pipeline into bedrock • channel armoring, in-channel structures, protective coatings, and erosion control measures • buoyancy control and pipeline protection measures • conduct routine pipeline corridor inspections • Trenchless crossing and/or pipe bridge span across major waterways (Queen Creek, Devil's Canyon, Mineral Creek) • locate crossings over major waterways outside areas of saturated reaches and perennial flow	**4.2.1, 4.2.2, 4.5.4**

Category	Potential Failure Mode	Defensive Design and Operational Measures	Details in Section
Hydrology and Hydrogeology (con't)	Sediment and erosion / exposed pipeline in water streams, pipe damage, spill, and shutdown	• gravel surface in pipeline corridor & road • upland runoff diverted to channels and culverts designed to 100-year discharge flow rates • revegetation as soon as practicable • sediment and erosion control – plan developed / equipment in place / team trained • conduct routine pipeline corridor inspections	**4.2.5, 4.3, 4.5.4**
Environment	Pipeline construction impact critical road, terrestrial or endangered aquatic biota	• cross environmental sensitive areas using other construction methods such as pipe bridge (Queen Creek, Devil's Canyon) or trenchless crossing (Mineral Creek) to avoid surface disturbance • cross highway 60 using horizontal directional drilling or boring to avoid traffic interruption • cross major waterways outside of the ordinary High-Water Mark (Queen Creek, Devil's Canyon and Mineral Creek) and outside critical habitat designations (Mineral Creek Gila Chub) • locate crossings over major waterways outside areas of saturated reaches and perennial flow	**4.2.6, 4.2.7**

	Threat of release of tails water or reclaimed water into environment	• compliant 24/7 leak detection / flow monitors in place
		• allow quick access for repairs
		• implement comprehensive pipeline integrity program that includes:
		  ○ maintain records for all available information about the integrity of the entire pipeline
		  ○ regular review of leak monitor data
		  ○ regular corridor inspections
		  ○ regular internal inspections using "smart-pigs"
		  ○ spill response – plan developed / equipment in place / team trained
			4.2.4, 4.2.5, 4.2.8, 4.6

Category	Potential Failure Mode	Defensive Design and Operational Measures	Details in Section
Construction Quality	Poor installation or welds results in pipe spills and shutdown	• QA/QC system in place during construction per various applicable codes and standards • conduct post-construction hydrotest in accordance with ASME B31.4 to prove the pipeline integrity • regular internal inspections using “smart-pigs” to monitor pipeline conditions	**4.2.3, 4.4, 4.5**
Operation and Maintenance	Planned or unexpected shutdowns results in tailings line blocking	• optimize route to keep pipe slope less than 15% as much as practicable • build pipeline tunnel to penetrate steep slope mountain ridge and maintain acceptable slope • flush tailings pipe regularly or during shutdowns either using backup power or emergency flush tank	**4.2.1, 4.5.5**
	Failures of pipeline corrosion control systems	• monitor pipeline external corrosion resistant coating • survey cathodic protection system that covers the entire pipeline length	**4.5.2**
Security	Malicious damage, vandalism or terrorism results in pipe damage, spill, and shutdown	• bury pipeline along the corridor as much as practicable • fence / gates at required locations, such as facilities, tunnel, bridge, etc. • maintain signs visible to the public around each facility, tunnel, bridge, road crossing, and water crossing location • conduct routine pipeline corridor inspections	**4.5.3, 4.5.4**

4.0 PREVENTION AND DETECTION OF PIPELINE FAILURES

4.1 General

Management of pipeline environmental protection involves various activities and procedures at different phases of the project. The success of the protection controls is highly dependent on thorough integration of the environmental objectives into the design of the pipelines and on proper implementation of spill monitor and control features, both during installation and when the pipes are operational.

4.2 Design Control Measures

All pipelines are designed in accordance with the relevant standards and guidelines, as listed previously in this document. The following control measures have been incorporated or taken into consideration in the design of the tailings corridor.

4.2.1 Pipeline Route Selection

If the pipe slope is too steep during a shutdown, the settled solids will slide down into the lower sections of the pipeline. Restart will generally be more difficult in such conditions since the entire cross section of the pipe at the bottom of the slope will be occupied by the solids. Therefore, the route has been optimized to maintain pipeline slope less than 15% as much as practicable.

In the Kings Crown Peak where it is impractical to maintain acceptable pipeline slope, multiple pipeline tunnel options were proposed and evaluated based on constructability, landowner feedbacks, and cost. The most suitable tunnel route has been selected to penetrate the ridge with a slope less than 15%.

Various regulators, agencies, communities, and landowners have been engaged, in particular during the DEIS comment period and during working group meetings. Pipeline route has been adjusted based on this feedback

The pipeline route will be optimized within the ROW to minimize environmental impact by reducing and balancing the amount of cut-and-fill and total overall disturbance. As much as is practicable, fill needs will be met with existing material on site, resulting in less disturbance.

Bends will be designed to minimize ground disturbance to the extent practicable and provide suitable distance to change direction or bend the selected pipe within their specified criteria without increasing risk of leaks.

4.2.2 Geohazards Mitigations

4.2.2.1 Unstable Slope Hazards

Slope instability is the most significant geohazard that could adversely affect safe operation of the pipeline. Geohazard assessments will be completed prior to construction along the selected alignment to identify locations where signs of active or historic landslides have been observed.

In locations where stability is a concern, site-specific geotechnical investigations will be carried out to understand the extent and characteristics of the instability for the purpose of selecting appropriate mitigation measures that could include:

- routing adjustments to avoid unstable slopes
- implementation of slope stabilization measures, including horizontal drains and/or toe buttressing, where applicable

- implementation of erosion protection measures, particularly at toe areas of watercourse crossings
- adapting construction methods to minimize surface disturbance and avoid reactivation of old slides
- selection of heavy wall pipe to increase the capacity of the pipeline to accommodate additional strains potentially induced by slides
- selection of low friction backfills to minimize the impact of potential slides, where required and applicable
- selection of reduced depth of cover to minimize the impact of potential slides and to facilitate strain relief, if necessary

4.2.2.2 Hydrotechnical Hazards

Where high potential for scour has been identified at watercourse crossings, engineering assessments will be done to formulate possible mitigation measures, including:

- routing adjustments to avoid areas of high energy concentration, if applicable
- additional depth of cover, extended zone of deep burial to accommodate potential scour, or both
- bank and bed protection using rip-rap materials
- pipe protection such as concrete coating and pipe shield, where applicable

Other construction methods, such as pipe bridge and trenchless crossings, are also considered to cross over major drainages above and outside the ordinary high-water mark of those drainages (i.e. Devil's Canyon, Queen Creek, Mineral Creek). Other major drainage channels along the corridor are designed to direct all adjacent natural runoff towards culverts that will control flow through the project site. These drainage structures are provided at fill areas to handle the runoff from storms and minimize the impact on existing natural water courses.

4.2.2.3 Seismic Hazards

Seismic events are typically not direct integrity threats to the pipelines, provided that the pipeline does not cross active faults. No records or signs of active faults have been identified along the selected pipeline alignment in the two seismic hazard evaluations completed for the area covering the pipeline and additionally, no active faults have been identified during field geotechnical investigations.

If signs of active fault zones are identified during construction of the pipeline, the following mitigation measures may be implemented depending upon the site conditions:

- heavy wall pipe to increase the capacity to accommodate additional stresses caused by differential movement in active fault zones
- increased trench width in combination with low density fill materials to minimize the additional stresses
- reduced depth of cover to minimize the additional stresses
- specially designed aboveground fault crossings, if necessary

4.2.2.4 Subsidence Hazards

If subsurface voids are encountered around any of these areas during pipeline construction, or are suspected to be present anywhere beneath the proposed pipeline, then a site-specific geophysical survey will be completed to approximate the extent of any subsurface voids and evaluate whether additional actions should be taken. If these conditions are not encountered or suspected, then no special actions will be taken beyond implementation of BMPs and BCPs during pipeline construction.

Please refer to Appendix B – Geohazard Assessment for additional details.

4.2.3 Pipeline Materials and Welding

The pipe will be made of carbon steel, low alloy-high strength that is able to withstand the internal pressures and external loads and pressures anticipated for the pipeline system. All mainline pipes in the corridor are designed with a nominal wall thickness of 1.25 inches and grade X70. The pipeline materials and thickness are selected specifically to maximize its life span and reduce pipeline replacement requirements.

All pipeline and fitting welding will be performed by a qualified welder or welding operator in accordance with welding procedures qualified under approved standards. Each welding procedure will be recorded in detail, including the results of the qualifying tests. This record will be retained and followed whenever the procedure is used.

Each weld will be inspected to ensure compliance with the engineering requirements. The weld inspection will be a visual inspection supplemented by suitable nondestructive testing.

4.2.4 Leak Detection

One of the main risks identified for the project is the potential to release either tailings or return water to the environment. The tailings and return pipelines will be monitored to detect leakage. The monitoring information will be used for alarm, interlock, and reporting functions. Multiple types of monitoring will be applicable to accommodate differing pipeline applications, the pipe installation, and to provide redundancy in the system.

The following methods will be used:

4.2.4.1 Flow and Pressure Monitoring

- Flow monitoring of recycle water and tailings lines will occur continuously. Measurements from each end of the pipelines will be input to the plant control system, and the values will be compared to evaluate leakage in the system. Pressure measurement and installation will be selected to suit each application with measuring points along the pipeline to support operation and the leak detection system.
- Closed-circuit television (CCTV) cameras at critical locations. Images will be available for recording / logging and will be displayed on monitors in the plant control room, security office, or other locations, as part of overall plant CCTV system.
- Regular inspections of complete pipeline system, system components (tunnel, bridge, etc.), and right-of-way.

4.2.4.2 Communications

Information will be delivered from the monitoring systems to the plant control systems using multiple methods:

- Pressure, flow, and density measurement analog signals using hard-wired connection to control system input modules at each end of the pipeline.
- CCTV as part of the fiber optic cabling / communications network.

4.2.4.3 Remote Monitoring Stations

It is estimated that three remote monitoring stations will be installed along the pipeline to collect information to support pipeline operation and monitoring (notably leak detection). Pressure will be measured in all pipelines at each station and transmitted to the central control room to verify proper operation. Estimated locations are at tunnel outlet, high point, between high point and skunk camp.

This will be a small building with roof-top solar to supply needed power. All parameters for the site will be monitored including but not limited to solar charging rate, battery status, building entry alarm to ensure proper function and security for the remote equipment. These alarms would allow RCM actions to correct if problems noted (such as theft of solar panels).

4.2.5 Access Roads

The pipeline corridor service road will run along the full length of the pipelines, at the same grade, to provide access between the concentrator and the TSF. The road will be interrupted at sensitive crossings (Queen Creek, Devil's Canyon and Mineral Creek) such that drive-around access will be required in some locations. The proposed road is designed to readily accommodate regular inspections and intermittent maintenance of the pipelines. This road will be designed to allow all-weather access and to prevent scouring and erosion. The pipeline corridor will be designed to allow for uninterrupted ranching and recreational use of existing Forest Services roads and to allow wildlife to pass through the area.

To reduce the risk of mechanical failure, the intent is to bury the pipeline along the entire length. Any section of the pipeline that is above ground will be buried or have on-surface barriers to prevent contact with equipment and vehicles. Additionally, the designated access road will ensure vehicles can travel along the length of the corridor separated from the above ground pipelines to prevent interaction.

Where required, fencing and gates will be installed to restrict public access and wildlife along the corridor and access road. Proper depth of cover and soil compaction will be maintained for the pipes where roads cross the pipelines.

The tailings corridor access road slopes away from the pipelines. This is combined with cutoff drains and bund walls that run along the length of the corridor into existing drainage paths. Rock protection will be provided for all drainage structures.

4.2.6 Trenchless Crossing

Environmental and engineering considerations are used to determine that trenchless construction would be the appropriate crossing methodology.

Trenchless crossings avoid traffic interruption, or in-stream works and ditching activities in the beds and banks of watercourses and avoid surface land disturbance. They can be installed in a number of different geotechnical conditions.

4.2.7 Pipe Bridge

Pipe bridges are proposed to cross Queen Creek and Devil's Canyon based on a combination of environmental and engineering considerations. Bridge will be selected to span the required widths with no obstructions, to minimize disturbance, and without the need for any intermediate supports along their length. The bridges across these two locations will be constructed outside of the ordinary high-water mark. This reduces environmental impact by minimizing disturbance and `eliminating any obstruction within the valleys and drainages.

A preliminary feasibility study of various pipe bridge options was performed to establish the preferred bridge type. Key considerations are site topography, constructability, environmental impact, and cost. Based on its advantages in constructability, minimum environmental impact, and least construction cost, the catenary cable bridge type is the recommended bridge type to build. The pipe bridge design will consider a maintenance vehicle path with enough width and load capacity to accommodate an H-10 service truck. This will allow quick responses any maintenance needs.

4.2.8 Corrosion Control Elements

The pipelines will be installed with an outer coating to prevent corrosion from ambient conditions in the pipe trench along the corridor. The primary coating for the external surface of the belowground pipe will be plant-applied fusion bonded epoxy. Field girth welds will be protected with a compatible liquid-applied coating. Abrasion-resistant coating will be used where pipe is installed using boring, drilling, or other methods that could cause abrasion to the coating during installation.

Additional mechanical protection systems such as sand padding, rock jacketing or rock shield will be used if large and/or angular backfill material is encountered.

In addition to the pipe coating, an impressed current cathodic protection (CP) system will be installed for the pipelines. The system will include ground beds and rectifiers. Where practical, the ground beds and rectifiers will be located at facility or remote sites where a convenient source of electrical power exists. Sacrificial anodes may also be used at specific locations.

Test points will be installed, where required, along the pipeline and at road, foreign pipeline, and utility crossings. These will allow the effectiveness of the operation of the system to be monitored during operation.

As high Voltage power line (115kV) will now be co-located with the pipeline within the same right of way, supplemental protection from induced alternating currents (AC) which could contribute to accelerated corrosion will be incorporated. This additional protection will comprise strategically placed anodes located in areas where the pipeline in the vicinity of the towers.

4.3 Stormwater Management

Before construction begins a stormwater pollution prevention plan, incorporating sediment and erosion controls, will be developed to describe how control measures are to be implemented and inspected, and to outline any requirements for analytical monitoring and recording. This will ensure that any areas prone to erosion and sediment flow during storms will be suitably controlled and stabilized, with drainage collection and diversion measures in place. A spill prevention and control plan will be prepared for both construction and operations, describing specific procedures for inspections, maintenance, incident actions and reporting, and emergency response.

4.4 Construction Control Measures

All pipelines will be fabricated and tested in accordance with the requirements of ASME B31.4 for quality assurance and quality control purposes. All pipelines will be tested using clean water at a test pressure that exceeds the maximum operating pressure to prove the pipeline system has adequate strength for operating conditions without leakage. The test records will be retained if the pipeline system tested is in use.

It is planned to construct the access road along the corridor first, together with drainage structures and sediment controls, so that the installation of pipelines, bridges, and other corridor facilities can proceed along a managed, contained access-way.

Daily activities during construction will include visual inspections as part of a routine monitoring program, good housekeeping, erosion control maintenance, pipeline construction QA/QC, and any necessary repairs. Similar activities, at an increased frequency, will be required during and after rainfall events.

Where required, fencing and gates will be installed to restrict public access and wildlife along the corridor and facilities. Signs will be maintained visible to the public around each facility, road crossing, water crossing, bridge, and tunnel. Each sign will contain the name of the operator and a telephone number where the operator can always be reached.

4.5 Operations Control Measures

Pipeline integrity is governed by its physical characteristics, its environment, and its operation and during operation, the pipeline will be managed by implementing the appropriate prevention and control measures and following a standard management approach (plan, implement, monitor, review, and revise). QA/QC systems will be in place to monitor operational compliance.

4.5.1 Internal Inspection Pigging (intelligent pigging)

Pigging in the context of pipelines refers to the practice of using devices known as “pigs” to perform various maintenance operations. This is completed without stopping the flow of the product in the pipeline. Pipeline pigs are devices that are placed inside the pipe and traverse the pipeline.

Internal inspection pigging is used primarily for defect monitoring, which enables potential problems to be identified and rectified well before leaks occur. Intelligent pigging is used as a tool for prevention of a leak by providing an assessment of pipeline integrity.

Intelligent pigging is carried out during the early period of pipeline operation to provide a baseline record of the pipe wall thickness and any anomalies that are present. Subsequent pig runs, as part of routine operations and preventive maintenance programs during the life of the operation, will identify any changes in wall thickness and the need for repairs.

4.5.2 Corrosion Protection Survey

A comprehensive aboveground coating evaluation survey shall be conducted on the mainline pipelines within 18 months but not sooner than 6 months following backfill to allow for settling and compaction.

This inspection is necessary to accomplish the following:

- Hold construction Contractors to quality metrics
- Identify pre-operation corrosion threats
- Identify regions where supplemental Cathodic Protection may be necessary
- Provide a catalogue of coating defects, including tabulated coordinates having minimum sub-meter accuracy that can later be correlated with future metal loss ILIs and close-interval Cathodic Protection surveys

Cathodic protection systems require periodic maintenance and testing to ensure that they are functioning properly. Generally, monthly checks are required to inspect exposed system components to ensure that equipment is intact. Potential damage to test stations, junction boxes, rectifier, or connections will be identified and repaired. Detailed yearly inspections and testing must be performed by qualified personnel, and the records should be reviewed by a qualified corrosion professional with follow up repairs completed by corrosion specialists.

4.5.3 Continuous Monitoring and Management

The operators will monitor flow, density, and pipeline pressures at selected locations in accordance with methods described in Section 4.2.4. A process-based pipeline leak detection system will be included with the control software and will continuously monitor conditions to identify any change that might indicate a potential leak. The operators will be notified of any potential event to permit immediate investigation.

A manual of written procedures will be prepared for conducting normal operations and maintenance activities and handling abnormal operations and emergencies. This manual will be reviewed regularly, and appropriate changes made as necessary to ensure that the manual is effective. This manual will be prepared before initial operations of a pipeline system commence.

4.5.4 Route Patrols

Regular patrols along the pipelines is a practical method of assessing all areas of the pipeline route. They are a visible reminder to people in the area of the presence of the pipeline and play a key role in preventing pipeline faults through third-party incidents. The patrols will ensure effective operation of the tailings corridor facilities and check for anomalies such as:

- pipeline leaks
- drainage sediment build-up, blockages and washouts
- access road erosion and damage
- pipe bridges and over / underpass damage
- landslides
- third party interference
- other potential hazards.

In addition to continual monitoring of pressure, flow, and leaks as well as CCTV monitoring, the pipelines will be patrolled to check for leaks and hazards and to ensure the security of the system. Consistent with CFR 49 Part 195, the route patrol will be conducted at intervals not exceeding 3 weeks, but at least 26 times each calendar year, to inspect the surface conditions on or adjacent to each pipeline right-of-way and each crossing under a navigable waterway will be inspected to determine the condition of the crossing. Methods of inspection include walking, driving, flying or other appropriate means of traversing the right-of-way.

4.5.5 Tailings Line Flushing

The tailings pipelines and recycled water lines will be flushed periodically using process water from the concentrator site to minimize line blocking and to align with regular preventive maintenance requirements.

During unexpected shutdowns, tailings lines should also be flushed to reduce the system start-up risk. Tailings lines can either be flushed from the concentrator site using emergency backup power supply or be flushed, as required, by the water stored in the flush tank placed at the high point.

4.6 Spill Response

RCM's General Plan of Operations includes information to be included in a Spill Prevention and Control Plan. Although spill response plans are developed to reflect specific facility designs, they generally include the following components:

- description of site operations
- leak detection procedures
- facility drainage systems
- spill prevention measures
- spare pipe, pipe clamps and other strategic supplies
- emergency and spill response and cleanup procedures
- spill reporting and notification procedures
- employee training and team drills.

RCM will have operators and staff working 24 hours per day throughout the life of the mine. Additional staff will be available on an emergency basis if needed during night shifts. Staff members will be supplied with radios for instant communication with the control room and other staff. The mine will own all necessary equipment or have contractors readily available on site for repair of a pipeline failure. Spill response kits will be stored at both ends of the tailings corridor, at the concentrator area, at the tailings administration complex, and also on the pipe bridges. The pipeline access road will provide reliable and immediate access to the full length of the line. If the situation requires additional resources or heavy equipment, they are readily available in nearby Globe-Miami or Phoenix / East Valley, Arizona.

Any suspected leak will be investigated. If a leak is identified, an appropriate prepared response plan will be initiated. This plan will include an evaluation of the need to stop the pumps or shut off the flow. Some leaks may be temporarily repaired safely without taking the pipe out of service. Any such temporary repair would be formally addressed during the next scheduled shutdown of the pipeline. Pipeline shutdowns are anticipated to be in line with concentrator shutdown timing.

Leaks will be evaluated by RCM staff to understand the root cause, quantity spilled, and regulatory reporting requirements.

Signature Page

Golder Associates Inc.

Wade Wang, PE
Senior Project Engineer

William J. Norwood
Pipeline Practice Leader/Principal

WW/WJN

APPENDIX A

Design Criteria

APPENDIX A

DESIGN CRITERIA - RESOLUTION COPPER MINE SKUNK CAMP PIPELINE CORRIDOR

1.0 CODES, STANDARDS, AND REFERENCES

The following code, standards and references will be used by Golder for best practice design basis for the Skunk Camp pipeline corridor:

- API (American Petroleum Institute)
  - Standard 650 Welded Tanks for Oil Storage
  - Specification 5L Line Pipe
  - 6D Specification for Pipeline Valves
  - RP 1102 Steel Pipelines Crossing Railroads and Highways
  - RP 1130 Computational Pipeline Monitoring for Liquid Pipelines
- ASME (American Society of Mechanical Engineers)
  - B16.5 Pipe Flanges and Flanged Fittings NPS ½ through NPS 24 Metric/Inch Standard
  - B16.9 Factory-Made Wrought Butt Welding Fittings
  - B16.11 Forged Fittings, Socket-Welding and Threaded
  - B16.34 Valves – Flanged, Threaded, and Welding End
  - B16.20 Metallic Gaskets for Pipe Flanges – Ring-Joint, Spiral-Wound, and Jacketed
  - B31.3 Process Piping
  - B31.4 Pipeline Transportation Systems for Liquids and Slurries
  - ASME/BPVC SEC VIII-1 Section VIII Division 1 Rules for Construction of Pressure Vessels
  - ASME BPVC IX Boiler and Pressure Vessel Code (BPVC), Section IX, Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operations
- ASTM (American Society for Testing and Materials)
  - A36/A36M Carbon Structural Steel
  - A105 Standard Specification for Carbon Steel Forgings for Piping Applications
  - A106 Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
  - A193 Standard Specification for Alloy-Steel and Stainless-Steel Bolting for High Temperature or High-Pressure Service and Other Special Purpose Applications
  - A194 Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure of High Temperature Service, or Both

- AWS (American Welding Society)
  - D1.1 Structural Welding Code – Steel Structural Welding Code – Steel
- AWWA (American Water Works Association)
  - M42 Steel Water-Storage Tanks
  - D100 Welded Carbon Steel Tanks for Water Storage
- CFR (Code of Federal Regulations)
  - 49 CFR Part 195 Transportation of Hazardous Liquids by Pipeline
- ICC (International Code Council)
  - IBC International Building Code
- NFPA (National Fire Protection Association)
  - 11 Standard for Low-, Medium-, and High-Expansion Foam
  - 30 Flammable and Combustible Liquids Code
  - 70 National Electrical Code
- MSS (Manufacturers Standardization Society)
  - SP 81 Stainless Steel, Bonnetless, Flanged Knife Gate Valves
  - SP 75 WPHY Pipe Fittings

2.0 SITE CONDITIONS

2.1 Design Temperatures

Based on the site location and ambient temperature changes throughout the year, the design temperatures assumed for this study are:

- Minimum Design Temperature: 0°F
- Installation Temperature: 60°F
- Maximum Design Temperature: 120°F

2.2 Design Life

The system design life is assumed to be 41 years per Mine Plan of Operations of Resolution Copper Mine.

2.3 Frost Depth

The site frost depth is 12 inches.

2.4 Mill Availability

The mill availability is assumed to be 92%.

3.0 HYDRAULIC ANALYSIS

3.1 Tailings Slurry Concentration

The weight percent solids and operating range solids concentration are determined by Resolution Copper Mine. The NPAG will be conveyed at a density of 60% solids and the PAG will be at 50% solids.

3.2 Design Throughput

Design flow rates for tailings slurry transport are calculated using the solid throughput along with the slurry specific gravity, calculated to be 1.73, and conversion factors. The tailings throughput would ramp up to 121,000 tons per day (tpd) for NPAG and 23,000 tpd for PAG by year 7 of the 41-year life of mine.

3.3 Tailings Particle Size Distribution

Physical characteristics of the PAG and NPAG tailings, both particle size distribution and rheology, are discussed below. These data were generated from bulk samples collected during past development activities and provided to Golder. The viscosity characteristics are will be adopted from the rheology data adopted from the Pilot scale testing.

3.3.1 NPAG Tailings

Table 2 shows the particle size distribution (PSD) for NPAG tailings that was used for the pipeline design. Table 3 presents the rheology for several ranges of percent solids. The specific gravity of the NPAG is 2.78.

Table 1: NPAG Tailings PSD

Size (µm)	US Mesh	Wt. % Retained	Cumulative Wt. % Passing	Cumulative Wt. % Retained
300	50	0.50	99.50	0.50
212	70	7.50	92.00	8.00
145	100	16.00	76.00	24.00
106	140	14.00	62.00	38.00
74	200	11.00	51.00	49.00
53	270	8.00	43.00	57.00
37	400	6.00	37.00	63.00
-37		37.00		
	Total	100%		

Note: Reference- Scavenger Tailings Cyclone- AVG Condition (KREBS)

- P_{95} - 244 microns
- P_{80} - 159 microns
- D_{50} – 71 microns

Table 2: NPAG Tailings Rheology

Percent Solids (Wt. %)	Coefficient of Rigidity (Pa)	Yield Stress (Pa)
72.4	0.210	45.4
70.7	0.121	33.5
66.9	0.054	14.1
60.9	0.022	4.3

Reference- Pocock 2015, Thickened Pyrite Rougher Tailings

3.3.2 PAG Tailings

Table 4 shows the particle size distribution (PSD) for PAG tailings that was used for the pipeline design. Table 5 presents the rheology for several ranges of percent solids. The specific gravity of the PAG is 3.5.

Table 3: PAG Tailings PSD

Size (µm)	US Mesh	Wt. % Retained	Cumulative Wt. % Passing	Cumulative Wt. % Retained
300	50	0.2	99.8	0.2
212	70	2.0	97.8	2.2
145	100	5.4	92.4	7.6
106	140	6.2	86.2	13.8
75	200	8.0	78.2	21.8
53	270	9.7	68.5	31.5
45	325	5.8	62.7	37.3
37	400	5.5	57.2	42.8
-37		57.3		
	Total	100%		

Note: Reference- Pyrite Tail Size Variability- Selective Flowsheet

- P_{95} - 177 microns
- P_{80} - 81 microns
- D_{50} - 31 microns

Table 4: PAG Tailings Rheology

Percent Solids (Wt. %)	Coefficient of Rigidity (Pa)	Yield Stress (Pa)
62.2	0.086	94.0
59.9	0.059	55.5
57.9	0.037	37.2
55.5	0.025	21.8

Reference- Pocock 2015, Thickened High Pyrite Tailings

3.4 Reclaim Water Properties

Reclaim water properties are assumed to be water properties at a fluid temperature of 70 degrees Fahrenheit.

3.5 Line Sizing Criteria

- Scavenger and pyrite tailings system

i) Maximum fluid velocity: 10 ft/s

ii) Minimum fluid velocity: 120% of calculated deposition velocity

- Reclaim water

i) Operating velocity of reclaim water is to be less than 10 ft/s to minimize pumping costs and pressure rating.

ii) Maximum operating pressure shall be less than the maximum allowable pressure per ASME B31.4.

4.0 PIPELINE AND MECHANICAL DESIGN BASIS

4.1 Pipeline Route Optimization in Response to DEIS Public Comments

The Skunk Camp North Pipeline route optimization process considers the following criteria, to the extent possible and practical, in the review and selection of alternatives to:

1) maintain pipeline slope no more than 15% as practical as possible

2) reduce the potential fragmentation of wildlife habitat

3) maximize the amount of temporary workspace located on existing disturbances

4) reduce the development of new access into remote areas

5) reduce the number and complexity of road, canyon, and watercourse crossings

6) avoid or reduce effects on identified environmentally sensitive areas

7) avoid or minimizing routing through areas of steep and unstable terrain

4.2 Pipeline Installation Method

Most of the proposed pipeline segments will be buried. Open trench installation method will be used for the pipeline construction except at the TSF and Concentrator (facility), tunnel, bridges, and trenchless crossing segments.

Trenchless installation methods, such as horizontal directional drilling (HDD), micro-tunneling, directional drilling and/or boring will be considered to bore a path underneath highway (US60), waterway, critical habitat, or proposed critical habitat (Mineral Creek) allowing for the pipe to be pulled through. Pipeline stress calculations will be completed to determine the bending, hoop and tensile stresses on the pipeline during installation and operating conditions. The calculations consider the pipe diameter, wall thickness, grade, depth and geometric design of the crossing.

4.3 Depth of Cover

The minimum depth of cover for the project will be equal or the greater of the depth of cover specified by ASME B31.4, and 49 CFR Part 195, as detailed below.

- Consolidated rock areas: 24 in.
- Road crossing areas: 48 in.
- Water crossing areas: 60 in. The requirement for increased burial depth will be evaluated and determined by the hydrology study at these locations in future phases.
- All other areas: 36 in.

4.4 Pipe Selection

4.4.1 Tailings Pipeline Material

Golder recommends the use of heavy wall carbon steel pipe for the NPAG line and HDPE-lined steel pipe for the PAG line.

4.4.2 Pipe Wall Thickness

The scavenger tailings transportation pipeline wall thickness is assumed to be 1.25 in to maximize the life span but remain exempt from post weld heat treatment requirements for each butt weld in accordance with ASME B31.4.

The pyrite tailings pipeline, the return water pipeline, and tailings process piping wall thickness will be determined based on fluid velocity and the design formula in ASME B31.4. This formula is used to calculate the required minimum wall thickness based on the yield strength of the pipe steel (determined by the grade of steel), maximum operating pressure, outside diameter, design factor, and weld joints.

All pipelines and facility piping are assumed to have the uniform nominal wall thickness throughout the span and the selected wall thickness would have higher allowable pressure than actual pressure. Actual pressure at specific points between the pump station and the receiving tank/sump is determined by calculating the change in hydrostatic pressure using the known elevation profile.

4.4.3 Slurry Corrosion/Erosion Rate

Golder has assumed an average wear rate of 24 mils (0.024 in) per year to estimate and optimize the scavenger pipe life span and the year of replacement. This average wear rate is obtained from actual yearly metal loss data from a benchmark site with similar tailings transportation system.

HDPE Liner for pyrite tailings pipeline would mitigates corrosion to negligible levels. Based on the extent of erosion, may require liner replacement which is analyzed to determine cost effectiveness against a rubber liner.

Historical data demonstrates that several factors can contribute to pipeline metal loss, including operating velocity, PSD, slurry pH, water quality, and dissolved oxygen content.

4.4.4 Pipe Specifications

Line pipe and facility piping specifications are summarized below:

- NPS 20 to 48: API 5L PSL2, Grade 70
- NPS 12 to 18: API 5L PSL2, Grade 60
- NPS 4 to 10: API 5L PSL2, Grade B
- NPS 3 or less: ASTM A106, Grade B

4.4.5 Valves and Fittings

- Whole tailings system valves will be flange to flange knife gate valves in accordance with MSS SP-81.
- Water system valves will be flange to flange, lugged-type butterfly, ball, or gate valves in accordance with API 6D and/or ASME B16.34.
- Pipe flanges and associated components will adhere to ASME B16.5, as applicable.
- Pipe fittings will adhere to MSS SP-75, ASME B16.9 or ASME B16.11, as applicable. All fittings used on whole tailings main pipeline shall be piggable.

4.5 Pipe Bend

Changes in pipeline alignment will be made with either field cold bends, shop fabricated hot bends (induction bends), or forged elbows.

All pipe bends shall have a minimum bend radius as specified below:

- Field bend: 40 x Pipe Diameter
- Hot bend: 6 x Pipe Diameter
- Elbow (whole tailings system): 5 x Pipe Diameter
- Elbow (return water system): 1.5 x Pipe Diameter

4.6 Corrosion/Erosion Control Elements

4.6.1 Pipe Coating

The coating systems used will be suitable for and specific to their application. Coating systems will meet or exceed current applicable industry codes and standards.

The primary coating for the external surface of the belowground pipe will be plant-applied fusion bonded epoxy. Field girth welds will be protected with a compatible liquid-applied coating.

Abrasion-resistant coating will be used where pipe is installed using boring, drilling or other methods that could cause abrasion to the coating during installation.

Additional mechanical protection systems such as sand padding, rock jacketing or rock shield will be used if large and/or angular backfill material is encountered.

4.6.2 Cathodic Protection

In addition to the pipe coating, an impressed current cathodic protection (CP) system will be installed for pipelines. The system will include ground beds and rectifiers, as determined during detailed design.

Where practical, the ground beds and rectifiers will be located at sites where a convenient source of electrical power exists nearby. Sacrificial anodes may also be used at specific locations, which will be identified during detailed design.

Test points will be installed, where required, along the pipeline and at road, foreign pipeline and utility crossings. These will allow the effectiveness of the operation of the system to be monitored during operation.

4.6.3 In-Line Inspection (ILI) Facilities

In-line inspection facilities, including launcher and receiver trap assemblies, will be installed to accommodate mainline ILI tools, cleaning tools and periodic maintenance activities.

The ILI system will be designed to ensure that the entire length of the tailings pipelines can be in-line inspected (excluding laterals and connections). Mainline launcher and receiver facilities will be in fenced areas at the West Plant and Skunk Camp TSF facility.

Launcher and receiver assemblies will be designed and constructed in accordance with ASME B31.4. Barrels will be removable pierces that can launch or receive the latest models of ILI tools and will be flanged to aid with removal for maintenance.

4.7 Water Crossing Design

Except for Queen Creek, Devil’s Canyon and Mineral Creek, all watercourses will be crossed using an open-cut crossing construction method. Given the relatively small size and low flows of most of the various watercourse crossings for the project, established trenched construction methods can be implemented with a high level of confidence.

4.8 Buoyancy Control

Along the pipeline route, conditions may exist under watercourses that require the implementation of buoyancy control measures using bolt-on weights. Weights and spacing are calculated based on empty pipe conditions.

4.9 Valve Placement

For tailings slurry pipelines, flanged valves are considered as potential leak points due to long term erosion. To minimize the effects of an accidental release, the design incorporates an approach where no mainline segment valves will be installed between the west plant and Skunk Camp TSF facility.

4.10 Leak Detection System

A computational pipeline monitoring (CPM) leak detection system will be considered at a high level in the study for the tailings pipelines in accordance with CFR 49 Part 195. The CPM system will comply with API RP 1130 in operating, maintaining, testing, record keeping, and dispatcher training of the system.

5.0 CIVIL AND STRUCTURAL DESIGN BASIS

5.1 Pipeline Tunnel and Borings

Pipeline tunnels will be considered for the segments with significant elevation change and steep slope to maintain less than 15% slope for the whole tailings pipeline. Pipeline tunnel and boring sections are planned based on geological data, tunnel length, access, and pipe constructability for the Silver King and Government Springs mountainous terrain areas as well as beneath US60.

5.2 Pipeline Bridge

A pipeline bridge option is part of the design for the Queen Creek and Devil's Canyon crossings. All pipelines installed on the bridge shall be designed to take the anticipated movements without exceeding the maximum allowable combined stress in accordance with ASME B31.4.

APPENDIX B

Geohazards Assessment

REPORT

GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

Arizona, USA

Submitted to:

Victoria Peacey
Resolution Copper Mine
102 Magma Heights Roads
Superior, AZ 85173

Submitted by:

Golder Associates Inc.

670 North Commercial Street, Suite 103 Manchester, New Hampshire, USA 03101

+1 603 668-0880

Project No. 1810598801

May 15, 2020

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1.0 INTRODUCTION

This report is a summary of the results of a Geohazards Assessment conducted by Golder Associates Inc. (Golder) for Rio Tinto's Resolution Copper Mining (Resolution) Skunk Camp Pipeline Route located in Pinal and Gila Counties, Arizona. The proposed Skunk Camp pipeline would contain tailing transportation pipelines and a return water pipeline that would connect West Plant to the proposed tailings storage facility (TSF) at Skunk Camp (Figure 1).

The approach to geohazards assessment for pipelines is a systematic process that begins with a regional-scale, desktop assessment, intended to identify and begin to characterize geohazards that could affect a pipeline during or post-construction. We consider geohazards to be natural geologic or hydrotechnical conditions, processes, and natural or induced events that could adversely affect the construction, operation, or integrity of a pipeline.

The assessment provides an overview of a proposed pipeline system by considering a range of possible geohazards that could potentially affect that system, based on available data. The scope of the assessment is established based on a combination of the natural environment where the pipeline system is located (i.e., geologic, topographic, and climatic conditions), the length of the pipeline system, the types of geohazards requested for consideration by the operator, the type and quality of resources available, and the desired output by the operator.

1.1 Scope of Work

The scope of work consisted of identifying potential geohazards along a 1,000 foot wide corridor centered on the proposed pipeline route through a desktop assessment. Hydrotechnical hazards (i.e., erosion and scour) were evaluated at pipeline crossing locations and where channel migration may encroach upon the pipeline.

For this assessment the following potential geohazards were considered:

- Unstable slopes, including landslides and rockfall;
- Seismic hazards, including surface fault rupture, soil liquefaction, and strong ground shaking;
- Potential ground subsidence associated with underground mines, fluid withdrawal (oil and gas or groundwater), and karst/pseudokarst; and
- Hydrotechnical hazards including erosion, scour and channel migration at watercourse crossings and followings.

2.0 METHODOLOGY

To identify and evaluate potential hazards, the following desktop activities were completed:

- Review of publicly available and site-specific geologic maps and applicable resources to assess whether particular geohazards or adverse geologic or hydrotechnical conditions, occur along the proposed pipeline route.
- Review of publicly available aerial imagery (e.g., Google Earth™, Esri™, and State imagery) and LiDAR data along the proposed pipeline route to identify, delineate, and characterize geomorphic indicators that appear consistent with active geohazards considered for this assessment.

Note: Project-specific LiDAR data and aerial imagery were unavailable for this review. Therefore, the results of the geomorphic review were limited by the quality of publicly available resources. Public LiDAR data were available for the segments of the pipeline located in Gila county (Arizona Geographic Information Council [AGIC] 2020). Some of the public LiDAR data and aerial imagery available during this assessment were not considered up-to-date; thus, ground conditions interpreted from these resources may not accurately reflect present-day ground conditions.

- Assignment of relative hazard classifications (e.g., low, moderate, and high) that are specific to the potential hazards identified during this assessment. The classification criteria we used are provided in Appendix A, along with the rationale for their development.
- Preparation of a geospatial Geographic Information System (GIS) database that provides the results of this assessment, including geographic coordinates, hazard classifications, data source identification, and comments for potential geohazards identified in this assessment.

3.0 PHYSIOGRAPHY AND GEOLOGIC SETTING

The proposed pipeline route is located within the Basin and Range physiographic province (National Park Service [NPS] 2017 and Vigil et al. 2008). The topography in the Basin and Range province is the result of regional extension of the crust which thinned and cracked the crust, creating large faults (generally trending in a north-south direction). Because of the extension, the region is marked by alternating linear mountain ranges and valleys. The mountains generally consist of late Precambrian and Paleozoic rocks which erode and fill the adjacent valleys with sediment. Much of the region drains internally, in an area known as the Great Basin, where surface water cannot reach the ocean (due to blockage of water movement by high mountains and lack of sufficient water).

The proposed pipeline route traverses three distinct geologic settings (Richard 2015; Cornwall et al. 1971; Horton 2017), as shown in Figure 1. The western portion of the proposed pipeline route primarily traverses Middle Proterozoic aged metamorphic and sedimentary rocks and Early Tertiary to Late Cretaceous granitic rocks. The central portion of the proposed pipeline route primarily traverses the Apache Leap Tuff, a Tertiary aged ash-flow tuff. The eastern portion of the proposed pipeline route primarily traverses Tertiary to Quaternary aged sedimentary rocks and basin deposits including alluvium, gravel, and conglomerate. The western portion of the proposed pipeline route crosses highly faulted terrain, while the central and eastern portions of the proposed pipeline route appear to cross less faulted terrain.

4.0 HAZARD CLASSIFICATION CRITERIA

Appendix A describes our approach to and rationale for assigning hazard classifications to each hazard identified during the desktop Geohazards Assessment.

Hazard classifications are tailored to be project-specific but are based on general classification criteria that are commonly used for assessing geohazards for pipelines. It should be noted that the hazard classifications are relative to each hazard. For example, a high hazard with respect to liquefaction does not necessarily mean that the pipeline has a high potential for damage in high hazard areas, but rather that the hazard from liquefaction is higher than in areas identified as low or moderate hazards. Likewise, the hazard classifications are relative to each individual hazard; for example, a high hazard fault is not necessarily equivalent in potential severity or likelihood to a high hazard karst subsidence feature.

Hazard classifications are also intended to lump together features or areas that have similar recommendations, including recommendations for mitigation, construction practices, or for possible additional assessment. That is, a high hazard classification may indicate that there is a high uncertainty from the desktop assessment of the potential threat, and thus additional assessment is recommended; it does not necessarily indicate that the area is at high risk from that hazard type.

5.0 RESULTS

The following sections provide a summary of results for each respective hazard. Overview maps outlining the geographic distribution of potential hazards are referenced, as applicable. General background information for each type of hazard, as well as our hazard criteria, are provided in Appendix A.

5.1 Unstable Slopes (Landslides)

To assess possible landslide hazards in the vicinity of the proposed pipeline route, geologic maps and datasets with mapped landslides (i.e., Arizona Geological Survey [AZGS] 2019) were reviewed. A geomorphic analysis of publicly available aerial imagery (i.e., Google Earth™ and ESRI) and 2018 1-meter resolution LiDAR data (available only in Gila County) (AGIC 2020) was also completed. The results of the assessment are limited by the resolution of the data available.

Possible landslides were identified that were completely or partially within 500 feet of the proposed pipeline centerlines (i.e., a 1,000 foot-wide corridor centered on the proposed pipeline centerline). Therefore, if a landslide had any portion of the feature fall within 500 feet of a proposed pipeline, the landslide was identified and delineated. A possible total of two low hazard landslides and two moderate hazard landslides were identified along the proposed pipeline route. The distribution of landslide hazards identified in this assessment is shown in Figure 2 and a summary of the results is provided in Table 1.

5.2 Unstable Slopes (Rockfalls)

The majority of the potential rockfall hazard areas are located within the central portion of the proposed pipeline route, where the route traverses the Apache Leap Tuff geologic unit. As described by Richard (2015), the Apache Leap Tuff is a crystal-rich (40-50%), plagioclase, embayed quartz, sanidine, biotite-bearing ash-flow tuff. The tuff ranges from unwelded to densely welded, and it rarely contains more than a few percent lithic fragments. Pumice fragments are also sparse and generally difficult to see in outcrop. The base and top of this unit are locally, crudely thick-bedded, but the unit generally appears massive. The majority of the area where the Apache Leap Tuff underlies the proposed pipeline route is also marked by steep slopes, which could be susceptible to rockfalls.

The distribution of rockfall hazard areas identified in this assessment is shown in Figure 2 and a summary of the results is provided in Table 1.

5.3 Seismic (Ground Shaking)

The potential hazard from earthquake wave propagation is commonly measured by the ground shaking parameter of peak horizontal ground acceleration (PGA), expressed as a percentage of the Earth's gravitational acceleration (g). To estimate possible hazards associated with ground shaking, seismic hazard mapping developed by the U.S. Geological Survey (USGS) for ground motions having a 10-percent probability of exceedance in 50 years, which represents a return period of 475 years (Petersen et al. 2014) were used.

The projected 475-year return period PGA value for the proposed pipeline route is 0.04 g, which is within the low hazard classification for seismic ground shaking (Figure 3; Table 1).

5.4 Seismic (Liquefaction)

Areas assumed to have liquefaction potential contain the following characteristics: (1) regularly or permanently saturated near the ground surface (e.g., less than 30 feet below ground surface); (2) contain relatively young (i.e., Holocene) alluvium, lacustrine (i.e., lake bed) deposits, or similar, that appear to consist of loose to moderately dense granular soils; and (3) subjected to strong ground shaking. Areas where these conditions appear to be present over a length of at least 300 feet along the proposed pipeline alignment were qualitatively identified, and then correlated with seismic hazard mapping for a return period of 475 years (Petersen et al. 2014) to classify their liquefaction hazard potential.

Areas within 500 feet of the proposed pipeline alignment that appeared to be underlain by alluvial or lacustrine deposits were identified and mapped using a combination of geologic maps, available LiDAR data, topographic maps, and aerial imagery. In general, it was assumed that relatively flat, low-lying areas adjacent to stream channels and lakes were underlain by liquefaction susceptible soil, i.e., alluvial or lacustrine deposits. Areas along the proposed pipeline route identified to contain potentially liquefiable soils were given a low hazard classification based upon the associated projected 475-year return period PGA value as described above in Section 5.3. (Figure 3; Table 2).

Conditions suitable for liquefaction are likely to be limited along the proposed pipeline alignment, due to the regionally dry climate and typically dry soil conditions for at least the first few feet of the subsurface. Eight areas were identified along the proposed pipeline alignment that appear to cross Quaternary alluvium. However, these waterbody crossings appear ephemeral in nature, and thus are ordinarily dry. For completeness, we have included these areas as low hazard liquefaction areas.

5.5 Seismic (Surface Fault Rupture)

Potential fault rupture hazards were assessed within 500 feet of the proposed pipeline route by reviewing the USGS Quaternary Fault and Fold Database for the United States (USGS 2018) and published geologic maps and reports to identify and evaluate active or potentially active faults and fault zones in close proximity to the proposed pipeline route.

No Quaternary-active faults in the vicinity of the proposed pipeline route were identified in the USGS Quaternary Fault and Fold Database (USGS 2018). However, several faults are mapped on larger scale geology maps that cross the proposed pipeline route, which appear to consist of older- (i.e., pre-Quaternary) and possibly younger- (i.e., Quaternary) aged faults. Information on the age of most recent movement along the faults was not readily available in the sources reviewed for this assessment (i.e., Richard 2015; Cornwall et al. 1971; Horton 2017). Based on review of these mapped faults in available LiDAR data and aerial imagery, and based on the reported results of field investigations conducted by Lettis Consultants International, Inc. (LCI 2020), no evidence of Quaternary-active faults was identified in vicinity of the proposed pipeline route. Thus, no surface fault rupture hazards within 500 feet of the proposed pipeline route were identified.

5.6 Subsidence (Karst)

Karst subsidence hazards were assessed within a 1,000 foot wide corridor, centered on the proposed pipeline alignment, by reviewing published geologic maps and reports to identify areas where carbonate bedrock and/or evaporites (e.g., salt, gypsum) are reported to be present at or near the ground surface along the proposed pipeline route. Relevant karst maps and reports were also reviewed, to identify areas where karst topography and karst features are reported to occur along the pipeline alignment. Finally, a geomorphic review of available LiDAR data and/or aerial imagery was completed to identify potentially hazardous karst features in the vicinity of the pipeline alignment.

Along portions of the western extent of the proposed pipeline route, we identified carbonate bedrock units to underlie the proposed pipelines (Richard 2015). One of the units underlying the proposed pipeline route, the Escabrosa Limestone, is reported in the region to contain karst features including caves and sinkholes (e.g., Cook 2018; Hill 1999; Richard 2015). Umbrella cave is reported to exist near the project area (unconfirmed third-party data) within the Escabrosa Limestone, although precise coordinates are unknown. We did not identify evidence of caves or sinkholes underlying the proposed pipeline route during review of available LiDAR data and/or aerial imagery, although features such as caves may not be evident at the surface.

As such, we identified areas along the proposed pipeline route underlain by the Escabrosa Limestone to be moderate hazard areas, and the remaining areas underlain by other carbonate bedrock units to be low hazard areas.

The distribution of karst subsidence hazard areas identified in this assessment are shown in Figure 4 and a summary of the results is provided in Table 3.

5.7 Subsidence (Underground Mine)

Underground mine subsidence hazards were assessed within a 1,000 foot wide corridor, centered on the proposed pipeline route by reviewing publicly available reports, maps, and databases along with data provided by Resolution, to identify any documented or suspected underground mines or mine features in the vicinity of the proposed pipeline route. Additional information about mining areas or operations identified in the vicinity of the proposed pipeline route was assessed to ascertain whether the occurrence and extent of underground mines are well documented or uncertain. This research was supplemented by reviewing available LiDAR data and/or aerial imagery to identify any topographic depressions observed around underground mines that are proximal to the pipeline.

In terms of the available digital GIS data that represent potential underground mine locations in the area of the proposed pipelines, only point data, representing approximate locations of underground mines and/or underground mine features were identified. The precise location and dimensions of underground mines is unclear from point datasets; thus, in evaluating potential subsidence hazards, we considered an area around each point to potentially contain an underground mine and related subsidence hazards.

Possible mine subsidence hazard areas were identified based on the following point data:

- Metallic and non-metallic mines from the Mineral Resources Data System (USGS 2005), with an operation type of underground, surface-underground, or unknown. The positional information for this dataset is highly variable. In the best cases this information was provided by plotting the location on a 7.5-minute topographic map; however, many records were located on the basis of published reports containing imprecise or scant information on the specific geographic location.
- Data provided by Resolution. These points were utilized to classify several moderate hazard areas (i.e., areas within 200 to 500 feet from each point) and high hazard areas (i.e., areas within 200 feet from each point). The remainder of the areas along the proposed pipeline route were classified as low hazard areas, as underground mining activities (past, present, and future) are known to occur in the region.

The distribution of underground mine subsidence hazard areas identified in this assessment is shown in Figure 5 and a summary of the results is provided in Table 4.

5.8 Subsidence (Fluid Withdrawal)

Fluid withdrawal subsidence hazards were assessed within a 1,000 foot wide corridor, centered on the proposed pipeline route, by reviewing publicly available resources to identify areas where the pipeline crosses major groundwater aquifers, oil and gas well fields, and/or areas reported to have experienced subsidence. The results of this review were supplemented by further researching additional information that was available, as well as reviewing available LiDAR data and/or aerial imagery, to ascertain the types, rates, and areas of influence for any applicable subsidence hazards identified in the vicinity of the pipeline.

No existing oil and gas fields or wells within 500 feet of the proposed pipeline route were identified. However, 13 areas along the eastern half of the proposed pipeline alignment were identified to be underlain by oil and gas parcels located on State Trust Land (Arizona State Land Department [ASLD] 2017), with no mapped oil and gas extraction wells (Arizona Department of Environmental Quality [ADEQ] 2019). These areas were assigned as low hazard fluid withdrawal subsidence areas.

Based on a study by Konikow (2013), the entirety of the proposed pipeline route appears to be underlain by an area reported to have cumulative groundwater depletion from 1900 and 2008 ranging between 0 and 400 cubic kilometers (Konikow 2013). The entire proposed pipeline route was thus classified as a moderate hazard area for possible groundwater-related subsidence.

The distribution of fluid withdrawal subsidence hazard areas identified in this assessment is shown in Figure 6 and a summary of the results is provided in Table 5.

5.9 Hydrotechnical Waterbody Crossings

Hydrotechnical hazards were assessed at pipeline waterbody crossing locations and where channel migration may encroach upon the pipeline using the USGS National Hydrography Dataset (USGS 2019) stream data. The stream locations were reviewed in Google Earth™ historical aerial imagery to assess current conditions and visible geomorphic processes to establish their hazard potential. A total of 60 drainage crossing locations were identified (Figure 6; Table 6). Crossings reviewed were primarily dry ephemeral channels and creeks. Review of these waterbodies also included available onsite photographs taken as part of previous corridor routing field reconnaissance. Engineering judgement and experience were used to identify and classify each waterbody crossing, as follows:

- 15 waterbody crossings as low hydrotechnical hazards.
- 16 waterbody crossings as moderate hydrotechnical hazards.
- 11 waterbody crossings as high hydrotechnical hazards.
- A total of 18 of the 60 waterbodies were assigned Non-Applicable as a hazard classification, at locations where the proposed pipeline route avoided the waterbody crossings by being located below the waterbody within a proposed tunnel.

6.0 CONCLUSIONS

This assessment based on a desktop review of existing information was intended to identify potential geohazards that might negatively affect construction and operation of the pipeline and to provide locations where further evaluation was required. All risks identified by this study will be considered with mitigation measures implemented during routing refinements, pipeline design, construction, and operation. Please refer to "CCC.03-81900-EP-REP-00007_Golder EIS Pipeline Protection and Integrity Plan" for detailed risk mitigations.

Golder Associates Inc.

Bailey Theriault, PG
Senior Geologist and Associate

David Thurman, PE
Senior Engineer

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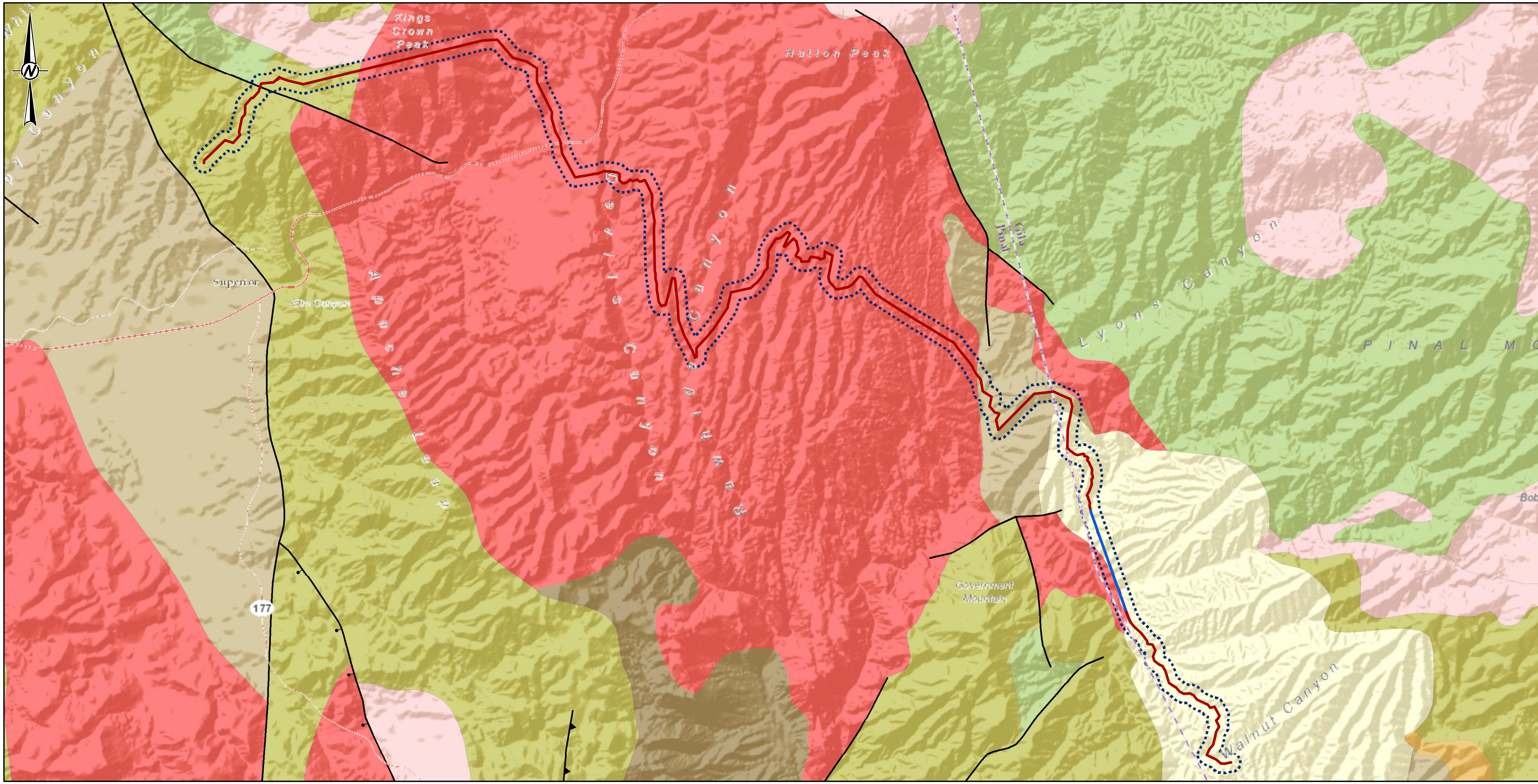
Figures



LEGEND

PROPOSED ALIGNMENT
- NORTH SKUNK CAMP
- REVISED TRENCHLESS CROSSING
- HAZARD ASSESSMENT CORRIDOR

GENERAL GEOLOGY UNIT
- IGNEOUS, INTRUSIVE
- IGNEOUS, VOLCANIC
- IGNEOUS AND SEDIMENTARY, UNDIFFERENTIATED
- METAMORPHIC, UNDIFFERENTIATED
- METAMORPHIC AND SEDIMENTARY, UNDIFFERENTIATED
- SEDIMENTARY, CLASTIC
- SEDIMENTARY, UNDIFFERENTIATED
- UNCONSOLIDATED, UNDIFFERENTIATED

GEOLOGIC STRUCTURE
- FAULT, UNKNOWN TYPE, CERTAIN
- NORMAL FAULT, CERTAIN (BALL ON DOWN SIDE)
- THRUST FAULT, CERTAIN (TEETH ON RIGHT FROM ORIGIN)

0 1 2
MILES

REFERENCE(S)
1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. GEOLOGIC MAP: HORTON 2017

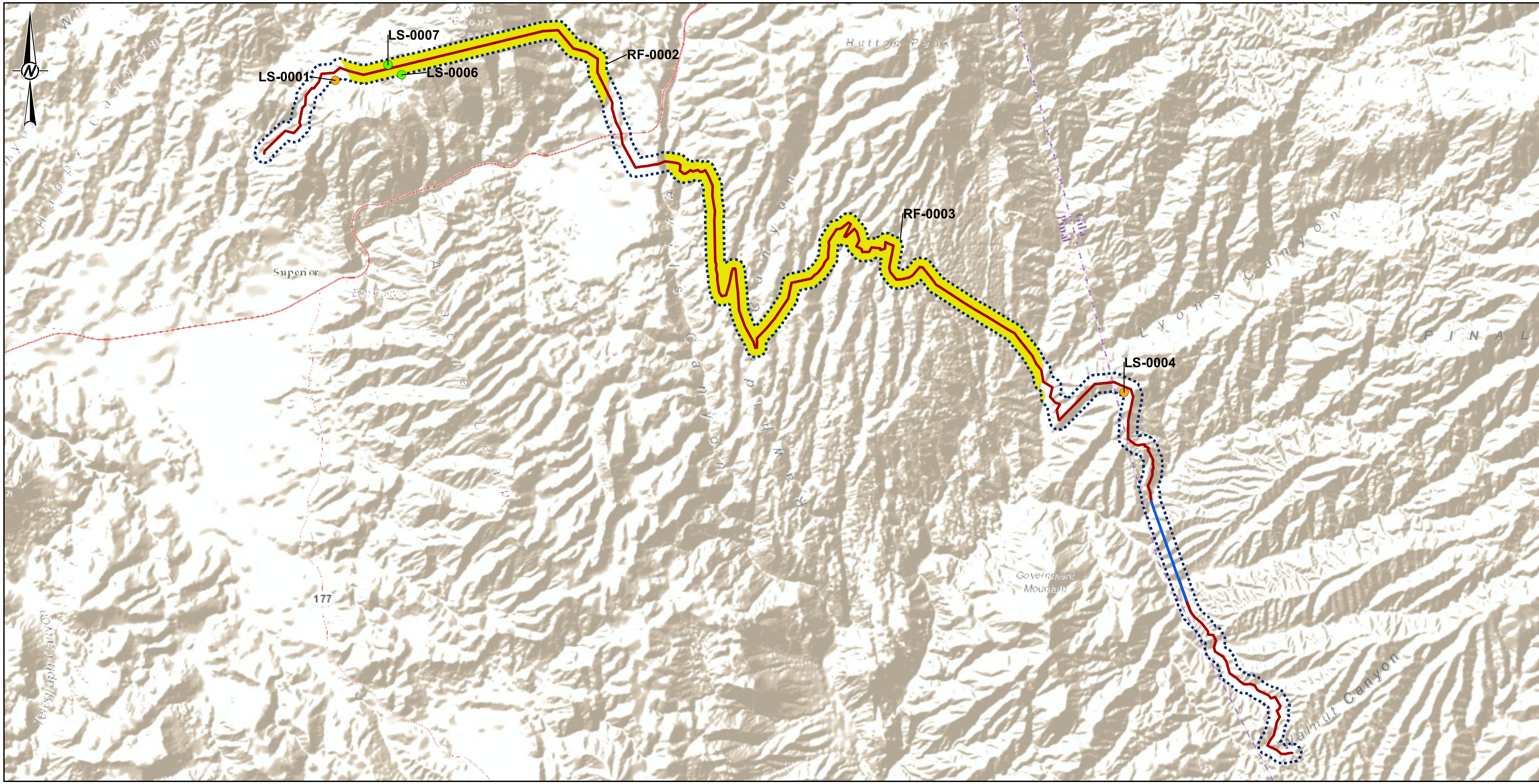
CLIENT	PROJECT
RESOLUTION COPPER MINE	GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

CONSULTANT: GOLDER

YYYY-MM-DD	5/13/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
PROJECT LOCATION MAP AND REGIONAL GEOLOGY

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	1



LEGEND

PROPOSED ALIGNMENT

NORTH SKUNK CAMP

REVISED TRENCHLESS CROSSING

HAZARD ASSESSMENT CORRIDOR

ROCKFALL HAZARD AREAS*

UNDEFINED

LANDSLIDE HAZARD AREAS*

LOW

MODERATE

0 1 2 MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT
RESOLUTION COPPER MINE

PROJECT
GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

CONSULTANT

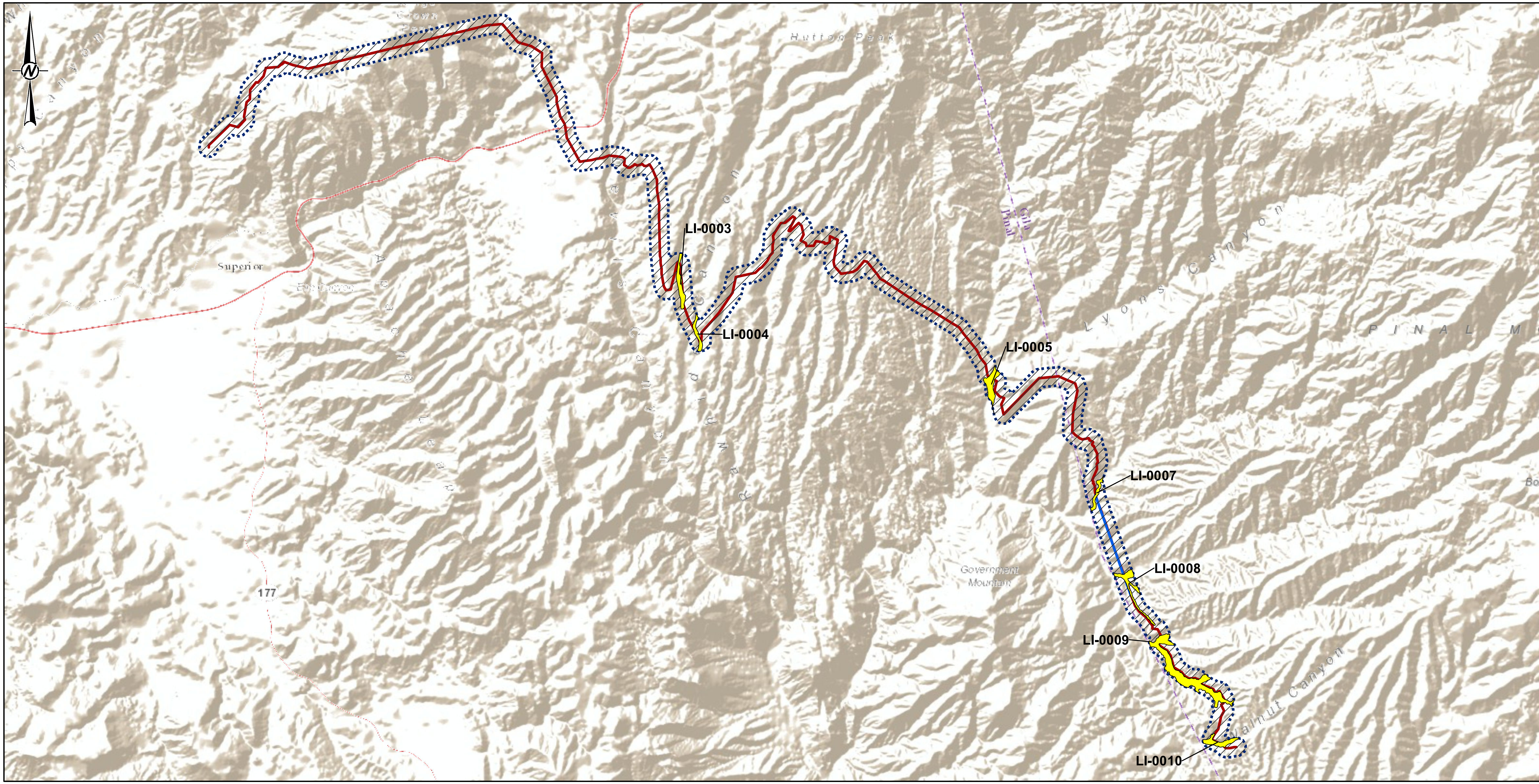
GOLDER

YYYY-MM-DD	5/14/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
LANDSLIDE AND ROCKFALL HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	2

*See Table A-1 for Hazard Classification Criteria



LEGEND

PROPOSED ALIGNMENT

NORTH SKUNK CAMP

REVISED TRENCHLESS CROSSING

HAZARD ASSESSMENT CORRIDOR

SEISMIC LIQUEFACTION HAZARD AREAS*

LOW

SEISMIC GROUND SHAKING HAZARD AREAS*

LOW

0 1 2

MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT

RESOLUTION COPPER MINE

PROJECT

GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

CONSULTANT

GOLDER

YYYY-MM-DD	5/13/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

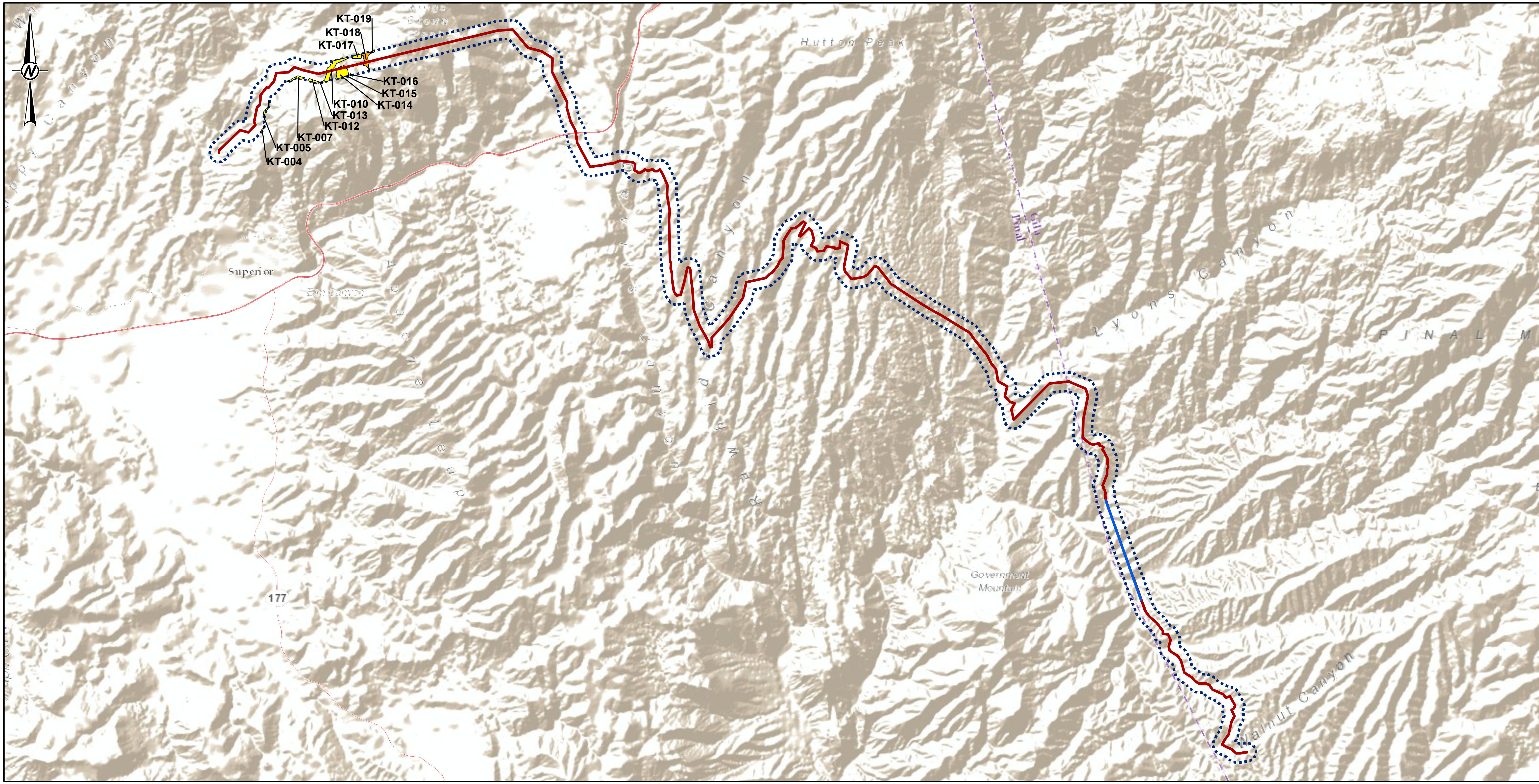
TITLE

SEISMIC HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	3

*See Table A-1 for Hazard Classification Criteria

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

PROPOSED ALIGNMENT

- NORTH SKUNK CAMP
- REVISED TRENCHLESS CROSSING
- HAZARD ASSESSMENT CORRIDOR

KARST SUBSIDENCE HAZARD AREAS*

- LOW
- MODERATE

*See Table A-1 for Hazard Classification Criteria

0 1 2
MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT
RESOLUTION COPPER MINE

PROJECT
GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

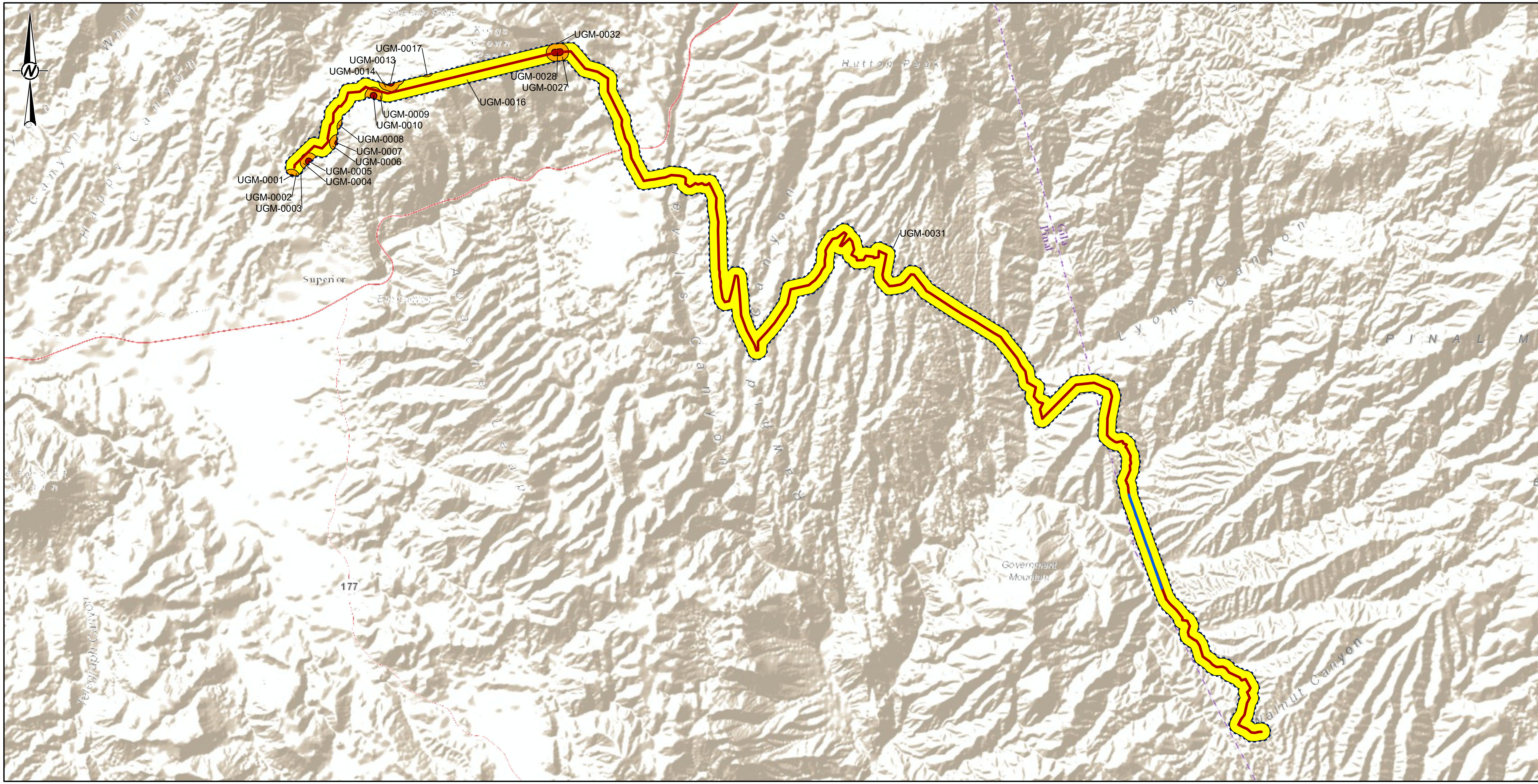
CONSULTANT
GOLDER

YYYY-MM-DD	5/13/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
KARST SUBSIDENCE HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

PROPOSED ALIGNMENT

- NORTH SKUNK CAMP
- REVISED TRENCHLESS CROSSING
- HAZARD ASSESSMENT CORRIDOR

UNDERGROUND MINE SUBSIDENCE HAZARD AREAS*

- LOW
- MODERATE
- HIGH

0 1 2
MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT
RESOLUTION COPPER MINE

PROJECT
GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

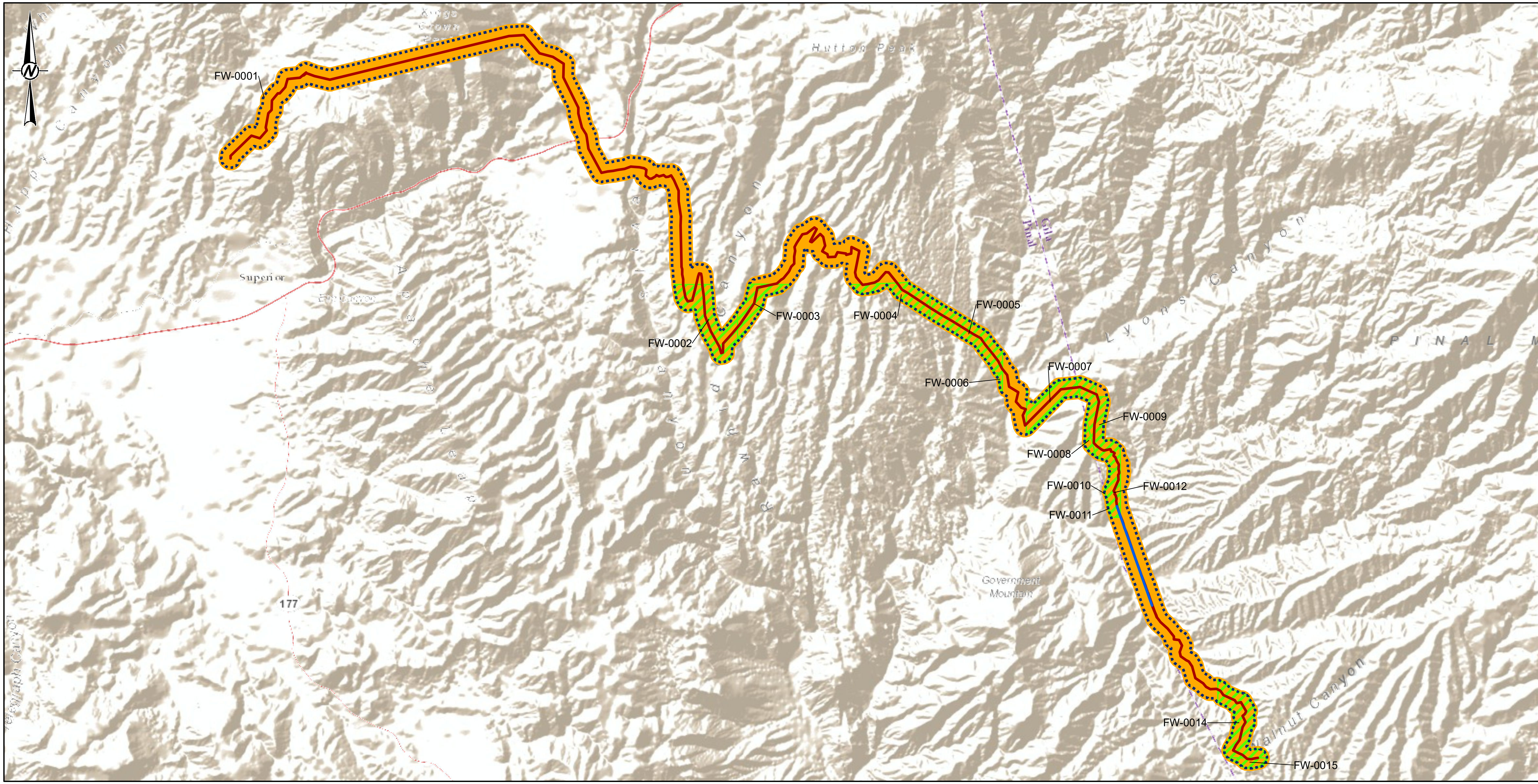
CONSULTANT
GOLDER

YYYY-MM-DD	5/13/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
UNDERGROUND MINE SUBSIDENCE HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	5

*See Table A-1 for Hazard Classification Criteria



LEGEND

PROPOSED ALIGNMENT

- NORTH SKUNK CAMP
- REVISED TRENCHLESS CROSSING
- HAZARD ASSESSMENT CORRIDOR

FLUID WITHDRAWAL SUBSIDENCE HAZARD AREAS*

- LOW (OIL AND GAS PARCELS)
- MODERATE (GROUNDWATER DEPLETION)

0 1 2

MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT
RESOLUTION COPPER MINE

PROJECT
GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

CONSULTANT

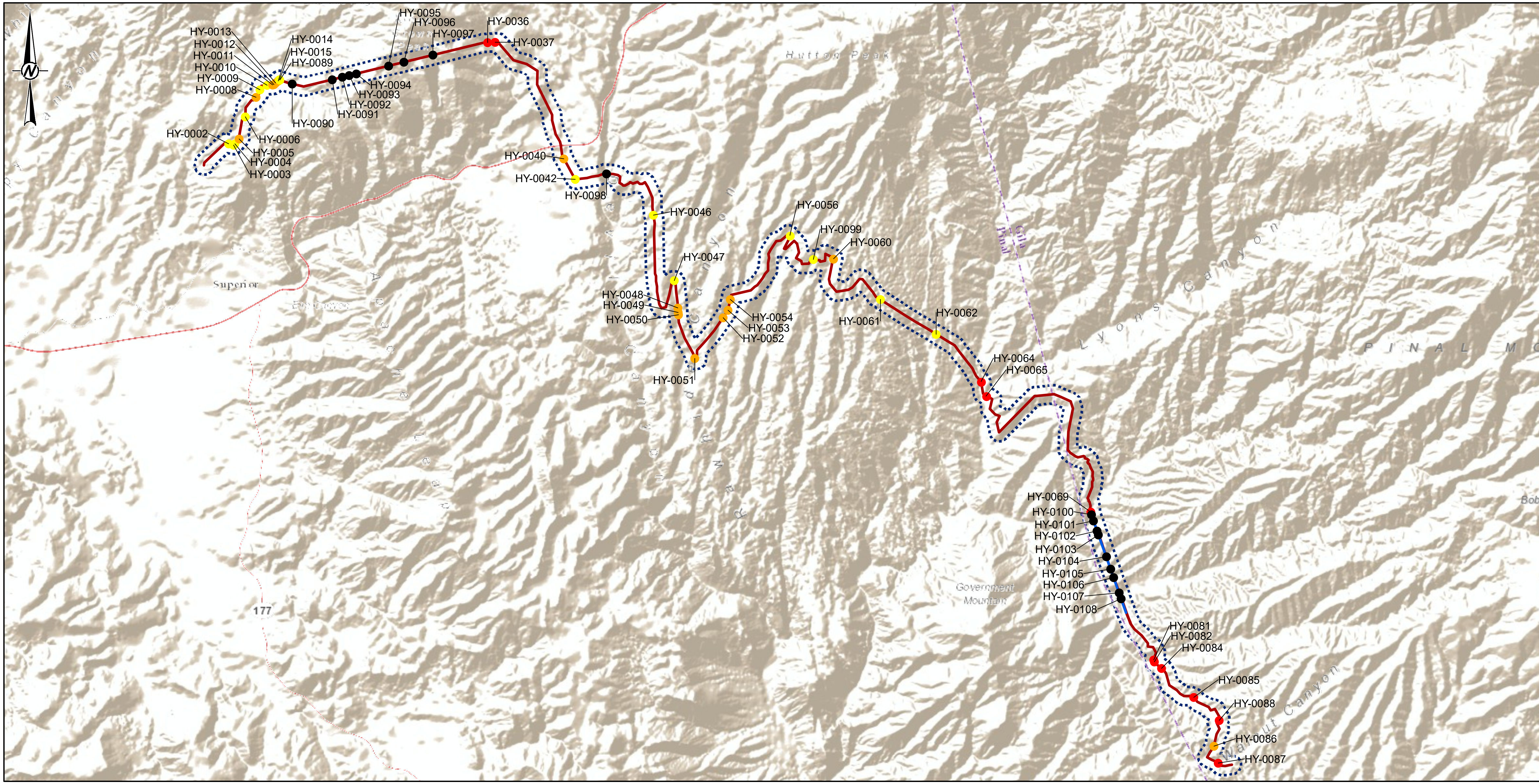
GOLDER

YYYY-MM-DD	5/13/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
FLUID WITHDRAWAL SUBSIDENCE HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	6

*See Table A-1 for Hazard Classification Criteria



LEGEND

PROPOSED ALIGNMENT

- NORTH SKUNK CAMP
- REVISED TRENCHLESS CROSSING
- HAZARD ASSESSMENT CORRIDOR

HYDROTECHNICAL HAZARDS (WATERBODY CROSSINGS)*

- LOW
- MODERATE
- HIGH
- N/A

*See Table A-1 for Hazard Classification Criteria

0 1 2
MILES

REFERENCE(S)

1. COORDINATE SYSTEM: NAD 1983 UTM ZONE 12N
2. IMAGERY SOURCES: ESRI, USGS, NOAA
SOURCES: ESRI, GARMIN, USGS, NPS
3. PIPELINES LOCATIONS PROVIDED BY RIO TINTO ON 5/11/2020.
4. COMPLETE REFERENCES FOR HAZARD DATA CAN BE FOUND IN THE ACCOMPANYING REPORT.

CLIENT
RESOLUTION COPPER MINE

PROJECT
GEOHAZARDS ASSESSMENT FOR THE SKUNK CAMP PIPELINE ROUTE

CONSULTANT
GOLDER

YYYY-MM-DD	5/15/2020
DESIGNED	N/A
PREPARED	TLM
REVIEWED	BLT
APPROVED	WW

TITLE
HYDROTECHNICAL WATERBODY CROSSING HAZARDS MAP

PROJECT NO.	CONTROL	REV.	FIGURE
1810598801	-	B	7

Tables

Table 1: Summary of Results – Landslide and Rockfall Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source
Landslide Hazards					
LS-0001	Moderate	33.322984	-111.094345	Possible debris flow where depositional area crosses the current proposed pipeline.	Google Earth
LS-0004	Moderate	33.275620	-110.952844	Possible active shallow landslide visible in LiDAR and imagery. Disturbance may be erosional in nature.	LiDAR; Google Earth
LS-0006	Low	33.323258	-111.081992	Possible debris flow. Possible excavuated area visible in Google Earth; depositional area not distinct.	Google Earth
LS-0007	Low	33.324763	-111.084397	Possible debris flow. Possible excavuated area visible in Google Earth; depositional area not distinct.	Google Earth
Rockfall Hazards					
RF-0002	Undefined	33.326336	-111.066350	Area with shallow or exposed fractured/fragmented bedrock with topographic relief sufficient for possible rockfall hazards to exist.	Horton 2017; Google Earth
RF-0003	Undefined	33.293636	-111.005882	Area with shallow or exposed fractured/fragmented bedrock with topographic relief sufficient for possible rockfall hazards to exist.	Horton 2017; Google Earth

Table 2: Summary of Results – Seismic Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source
Ground Shaking Hazards					
GS-0001	Low	33.288904	-111.005125	PGA 0.04 g	Petersen et al. 2014
Liquefaction Hazards					
LI-0003	Low	33.291010	-111.022163	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0004	Low	33.283445	-111.019114	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0005	Low	33.275876	-110.966572	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0007	Low	33.259476	-110.947773	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0008	Low	33.245280	-110.941509	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0009	Low	33.232605	-110.931855	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014
LI-0010	Low	33.222213	-110.925988	Potential liquefaction conditions present in area where PGA is <0.1 g.	Mapped by Golder based on Google Earth Imagery; Petersen et al. 2014

Table 3: Summary of Results – Karst Subsidence Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source
KT-004	Low	33.314931	-111.098754	Mescal Limestone (Ym); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-005	Low	33.317896	-111.098106	Mescal Limestone (Ym); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-007	Low	33.322619	-111.092659	Mescal Limestone (Ym); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-010	Low	33.323997	-111.086333	Mescal Limestone (Ym); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-012	Low	33.322212	-111.089644	Martin Limestone (Dm); Geologic Unit Lithology: Dolomitic or magnesian sedimentary rock	Richard 2015
KT-013	Moderate	33.321960	-111.088496	Escabrosa Limestone (Me); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-014	Low	33.323546	-111.084541	Martin Limestone (Dm); Geologic Unit Lithology: Dolomitic or magnesian sedimentary rock	Richard 2015
KT-015	Moderate	33.322936	-111.083791	Escabrosa Limestone (Me); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-016	Moderate	33.323205	-111.082995	Escabrosa Limestone (Me); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-017	Low	33.325854	-111.081771	Martin Limestone (Dm); Geologic Unit Lithology: Dolomitic or magnesian sedimentary rock	Richard 2015
KT-018	Moderate	33.325510	-111.080191	Escabrosa Limestone (Me); Geologic Unit Lithology: Calcareous carbonate sedimentary rock	Richard 2015
KT-019	Low	33.326613	-111.079100	Martin Limestone (Dm); Geologic Unit Lithology: Dolomitic or magnesian sedimentary rock	Richard 2015

Table 4: Summary of Results – Underground Mine Subsidence Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source	Site Name	Mine Name(s)	Operation Type	Main Commodity
UGM-0001	High	33.310202	-111.106952	Area within 200 feet of a point representing an underground mine location.	USGS 2005	Magma Apex Property	Magma Extension	Underground	Silver, Manganese
UGM-0002	Moderate	33.310636	-111.106799	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Magma Apex Property	Magma Extension	Underground	Silver, Manganese
UGM-0003	Moderate	33.310606	-111.105257	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Sam Thorpe Mining Co Property	West Horn Silver, Prince, Rainbow, New Telluride, Black Prince	Underground	Gold, Silver
UGM-0004	Moderate	33.312736	-111.104176	Area 200-500 feet from a point representing a portal (Resolution Portal: SP_West_Portal).	Resolution		Resolution	Underground	
UGM-0005	High	33.312488	-111.103890	Area within 200 feet of a point representing an underground mine location (Resolution Portal: SP_West_Portal).	Resolution		Resolution	Underground	
UGM-0006	Moderate	33.315580	-111.099153	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Magma Chief Copper Mine	Magma Chief Mine	Unknown	Silver
UGM-0007	High	33.315426	-111.098612	Area within 200 feet of a point representing an underground mine location.	USGS 2005	Magma Chief Copper Mine	Magma Chief Mine	Unknown	Silver
UGM-0008	Moderate	33.318298	-111.097990	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Magma Chief Group	Patented Claims M S 3482, Patented Claim M S 3483	Underground	Lead, Manganese, Silver, Zinc
UGM-0009	Moderate	33.323307	-111.091388	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Baltimore		Underground	Manganese, Silver
UGM-0010	High	33.322907	-111.091492	Area within 200 feet of a point representing an underground mine location.	USGS 2005	Baltimore		Underground	Manganese, Silver
UGM-0013	High	33.324664	-111.088254	Area within 200 feet of a point representing an underground mine location (Resolution Portals: National West Portal & CS_West_Portal).	Resolution		Resolution	Underground	
UGM-0014	Moderate	33.324385	-111.088225	Area 200-500 feet from a point representing a portal (Resolution Portals: National West Portal & CS_West_Portal & Havaliena West Portal).	Resolution		Resolution	Underground	

Table 4: Summary of Results – Underground Mine Subsidence Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source	Site Name	Mine Name(s)	Operation Type	Main Commodity
UGM-0016	Low	33.323184	-111.084239	Area where underground mines are reported to be relatively common in the vicinity of the proposed pipeline centerline, but no evidence of underground mines, related features, or surface subsidence was identified within 500 feet of the proposed pipeline centerline based on the available resources.	Based on regional presence of mining				
UGM-0017	Moderate	33.326121	-111.081163	Area 200-500 feet from a point representing an underground mine location.	USGS 2005	Apache		Underground	Copper, Silver
UGM-0027	Moderate	33.329843	-111.056552	Area 200-500 feet from a point representing a portal (Resolution Portals: Havaliena East Portal; Queens Creek East Portal; QC_East_Portal).	Resolution		Resolution	Underground	
UGM-0028	High	33.329840	-111.056550	Area within 200 feet of a point representing an underground mine location (Resolution Portals: Havaliena East Portal; Queens Creek East Portal; QC_East_Portal).	Resolution		Resolution	Underground	
UGM-0031	Low	33.281048	-110.986992	Area where underground mines are reported to be relatively common in the vicinity of the proposed pipeline centerline, but no evidence of underground mines, related features, or surface subsidence was identified within 500 feet of the proposed pipeline centerline based on the available resources.	Based on regional presence of mining				
UGM-0032	Low	33.331201	-111.056723	Area where underground mines are reported to be relatively common in the vicinity of the proposed pipeline centerline, but no evidence of underground mines, related features, or surface subsidence was identified within 500 feet of the proposed pipeline centerline based on the available resources.	Based on regional presence of mining				

Table 5: Summary of Results – Fluid Withdrawal Subsidence Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source
FW-0001	Moderate	33.288904	-111.005125	Groundwater aquifers in the US that show depletion over the period 1900-2008.	Konikow 2013
FW-0002	Low	33.287347	-111.021007	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0003	Low	33.289552	-111.012734	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0004	Low	33.291017	-110.986568	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0005	Low	33.285150	-110.974539	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0006	Low	33.278207	-110.968892	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0007	Low	33.274924	-110.960006	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0008	Low	33.269134	-110.953044	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0009	Low	33.271547	-110.951213	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0010	Low	33.261121	-110.950120	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0011	Low	33.258819	-110.949450	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0012	Low	33.261288	-110.948546	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0014	Low	33.226697	-110.926191	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019
FW-0015	Low	33.220810	-110.924206	Oil and gas parcel on AZ State Trust land, with no known extraction wells.	Arizona State Land Department 2017; Arizona Department of Environmental Quality 2019

Table 6: Summary of Results – Hydrotechnical Waterbody Crossing Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source	Stream Name (NHD)	Feature Type (NHD)	Stream Type (NHD)
HY-0002	Low	33.314692	-111.102102		Identified by Golder from aerial imagery (Google Earth)			
HY-0003	Low	33.314487	-111.101255		Identified by Golder from aerial imagery (Google Earth)			
HY-0004	Low	33.314686	-111.101040		Identified by Golder from aerial imagery (Google Earth)			
HY-0005	Moderate	33.315424	-111.100244		NHD		Stream/River	Ephemeral
HY-0006	Low	33.318718	-111.099183		Identified by Golder from aerial imagery (Google Earth)			
HY-0008	Moderate	33.321693	-111.097218	Headcut potential from downstream side of road	NHD		Stream/River	Ephemeral
HY-0009	Low	33.322788	-111.096513		NHD		Stream/River	Ephemeral
HY-0010	Low	33.323466	-111.095232		Identified by Golder from aerial imagery (Google Earth)			
HY-0011	Moderate	33.323541	-111.094259		Identified by Golder from aerial imagery (Google Earth)			
HY-0012	Moderate	33.323580	-111.094040	Almost follows pipeline	NHD		Stream/River	Ephemeral
HY-0013	Moderate	33.323810	-111.093722	Steep drainage with incision potential	Identified by Golder from aerial imagery (Google Earth)			
HY-0014	Moderate	33.324123	-111.093290	Steep drainage with incision potential	Identified by Golder from aerial imagery (Google Earth)			
HY-0015	Low	33.324306	-111.093037		NHD	Conley Spring Wash	Stream/River	Ephemeral
HY-0036	High	33.329889	-111.055838	Location of tunnel exit is within active erosion area	NHD		Stream/River	Ephemeral
HY-0037	High	33.329966	-111.054488	Active bed channel crossing road	NHD	Queen Creek	Stream/River	Intermittent
HY-0040	Moderate	33.312475	-111.042179	Active bed within meander bend	NHD		Stream/River	Ephemeral
HY-0042	Low	33.309384	-111.040185	Within road impoundment pond	NHD		Stream/River	Ephemeral
HY-0046	Low	33.304026	-111.026186		NHD		Stream/River	Ephemeral
HY-0047	Low	33.294197	-111.022474		NHD		Stream/River	Ephemeral
HY-0048	Moderate	33.290078	-111.021799		NHD		Stream/River	Ephemeral
HY-0049	Moderate	33.289383	-111.021743		NHD		Stream/River	Ephemeral
HY-0050	Moderate	33.289058	-111.021717		NHD		Stream/River	Ephemeral
HY-0051	Moderate	33.282519	-111.018807		NHD		Stream/River	Ephemeral
HY-0052	Moderate	33.288617	-111.013737	Following downstream of cattle tank	NHD		Stream/River	Ephemeral
HY-0053	Moderate	33.289742	-111.012849	Following downstream of cattle tank	NHD		Stream/River	Ephemeral
HY-0054	Moderate	33.291357	-111.012425	Cattle Tank/Following	NHD		Stream/River	Ephemeral
HY-0056	Low	33.300891	-111.001708		NHD		Stream/River	Ephemeral
HY-0060	Moderate	33.297395	-110.994015		NHD		Stream/River	Ephemeral
HY-0061	Low	33.291368	-110.985609	Boulders through crossing	NHD		Stream/River	Ephemeral
HY-0062	Low	33.286134	-110.975650	Boulders through crossing	NHD		Stream/River	Ephemeral
HY-0064	High	33.278929	-110.967577	Meandering dynamic creek	NHD	Dry Wash Mineral Creek	Stream/River	Intermittent
HY-0065	High	33.276777	-110.966606	Wide floodplain with evidence of meandering	NHD	Lyons Fork	Stream/River	Intermittent
HY-0069	High	33.259429	-110.948019	Dynamic location at confluence	NHD	Milky Wash	Stream/River	Intermittent

Table 6: Summary of Results – Hydrotechnical Waterbody Crossing Hazards

Hazard ID	Hazard Classification	Latitude	Longitude	Comments	Source	Stream Name (NHD)	Feature Type (NHD)	Stream Type (NHD)
HY-0081	High	33.237232	-110.936780		NHD		Stream/River	Ephemeral
HY-0082	High	33.236925	-110.936685		NHD	Cedar Creek	Stream/River	Intermittent
HY-0084	High	33.235933	-110.935429	Meandering channel following road and alignment	Identified by Golder from aerial imagery (Google Earth)			
HY-0085	High	33.231566	-110.929639		NHD		Stream/River	Ephemeral
HY-0086	Moderate	33.224254	-110.926051		Identified by Golder from aerial imagery (Google Earth)			
HY-0087	High	33.221693	-110.925300		NHD		Stream/River	Ephemeral
HY-0088	High	33.228100	-110.925143	Headcut potential from downstream side of road	NHD		Stream/River	Ephemeral
HY-0089	Low	33.324265	-111.092973	NEW	NHD	Conley Spring Wash	Stream/River	Ephemeral
HY-0090	N/A	33.323683	-111.090750	Tunnel	NHD		Stream/River	Ephemeral
HY-0091	N/A	33.324338	-111.083616	Tunnel	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0092	N/A	33.324711	-111.081794	Tunnel	NHD		Stream/River	Ephemeral
HY-0093	N/A	33.324945	-111.080595	Tunnel	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0094	N/A	33.325211	-111.079306	Tunnel	NHD		Stream/River	Ephemeral
HY-0095	N/A	33.326400	-111.073552	Tunnel	NHD		Stream/River	Ephemeral
HY-0096	N/A	33.326965	-111.070794	Tunnel	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0097	N/A	33.328024	-111.065606	Tunnel	NHD		Stream/River	Ephemeral
HY-0098	N/A	33.310237	-111.034598	Bridge	NHD		Stream/River	Intermittent
HY-0099	Low	33.297356	-110.997591		NHD		Stream/River	Ephemeral
HY-0100	N/A	33.259009	-110.947906	Trenchless	NHD	Milky Wash	Stream/River	Intermittent
HY-0101	N/A	33.258097	-110.947528	Trenchless	NHD		Stream/River	Ephemeral
HY-0102	N/A	33.256568	-110.946896	Trenchless	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0103	N/A	33.255982	-110.946671	Trenchless	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0104	N/A	33.252692	-110.945259	Trenchless	NHD		Stream/River	Ephemeral
HY-0105	N/A	33.250862	-110.944488	Trenchless	NHD	Mineral Creek	Stream/River	Intermittent
HY-0106	N/A	33.249566	-110.943941	Trenchless	Identified by Golder from aerial imagery (Google Earth & ESRI)			
HY-0107	N/A	33.247298	-110.942989	Trenchless	NHD	Mill Creek	Stream/River	Intermittent
HY-0108	N/A	33.246412	-110.942603	Trenchless	NHD		Stream/River	Ephemeral

APPENDIX A

Classification Criteria for Geohazard Assessments

1.0 CLASSIFICATION CRITERIA FOR PHASE I GEOHAZARD ASSESSMENTS

The following sections provide a brief introduction to the respective geohazard and describe our approach toward identification and classification of geohazards for Phase I Assessments. The rationale used to develop our hazard classification criteria are provided for each section. The hazard criteria presented are project-specific but are based on typical classification schemes used for Geohazard Assessments for pipelines. Table A-1 provides a summary list of our classification criteria.

1.1 Unstable Slopes (Landslides)

A landslide is the "movement of a mass of rock, debris, or earth down a slope" and encompasses geologic processes such as debris or mud flows, rotational slides (slumps), translational slides, earth flows, rockfalls, or debris slides (Cruden 1991; Cruden and Varnes 1996). Landslide hazards can potentially pose a serious threat to pipeline integrity because the nature and magnitude of ground movement can impose differential loading on pipelines that may ultimately exceed pipe strength capacity (INGAA 2016). Landslides can damage pipelines by shearing or bending the pipe along the lateral limits or failure planes of the landslide, by compressing and tensioning the pipe during downslope movement of soil and rock, by undercutting and exposing the pipe (in the event that material flows out from underneath the pipeline), or by physically impacting the pipe in the event of a rapid debris flow or rockfall.

Landslide hazard classifications are based on the apparent threat to a pipeline from a landslide during or post-construction, and are based on a combination of the landslide characteristics such as size, type, and nature and level of activity, and the spatial relationship of the landslide to the pipeline. For this assessment, we have addressed rockfall hazards separately from other types of landslides (see Section 1.2).

Our landslide hazard classifications are as follows:

<u>Low Hazard</u>

In general, a low hazard landslide is a mapped landslide location that appears to have a low potential to impact the pipeline. A low hazard landslide is defined as a:

- Dormant or relict landslide crossed by or within 20 feet of a proposed pipeline centerline with low potential for renewed activity.
- Landslide (of any age) located between 20 and 100 feet of the proposed pipeline centerline.
- Active or recently active landslide that has been mitigated or repaired, which shows no signs of new ground movement post-repair.

Justification: In some instances, landslides may have occurred under climatic or topographic conditions that are no longer present, such as the climatic condition present during the latest Pleistocene[1] and early Holocene[2] (Cruden and Varnes 1996). If a landslide could be clearly identified as dormant or relict, and appeared to have a low potential for reactivation, the landslide was classified as a low hazard.

A landslide in close proximity to but not actually crossing a pipeline centerline may represent a long-term potential hazard to a pipeline, but probably does not pose an imminent threat.

[1] The time period from approximately 10,000 years ago to about 50,000 years ago (Walker and Geissman 2009).
[2] The period from approximately 5,000 to 10,000 years ago (Walker and Geissman 2009).

A landslide that has been mitigated or repaired may have a decreased potential for future ground movement if the conditions which caused the initial failure have been altered or removed during the mitigation process. Although a mitigated or repaired landslide may still have the potential for future ground movement, a lack of evidence of post-repair movement is assumed to indicate at least a temporary state of stability has been obtained for the landslide.

Moderate Hazard

In general, a moderate hazard landslide is a mapped landslide location where it does not appear that the pipeline will likely be impacted, based on the current footprint and/or activity level of the landslide, but where the pipeline may have the potential to be impacted with the enlargement or reactivation of the landslide. A moderate hazard landslide is defined as an:

- Active or recently active landslide with geomorphic or instrumental evidence of disturbance within 5 to 20 feet of the proposed pipeline centerline.
- Debris flow where the run-out/depositional area is crossed by a proposed pipeline centerline.

Justification: A landslide in close proximity to but not actually crossing a pipeline centerline may represent a potential future hazard to a pipeline if the landslide reactivates or expands toward the pipeline. Landslides could also be sensitive to disturbance during or after construction (i.e., a landslide could be triggered or reactivated in these areas), and existing landslides in proximity to the alignment could enlarge (such as from landslide retrogression) and intersect the alignment at a future time.

High Hazard

In general, a high hazard landslide is a mapped landslide location where it appears that there may be an immediate threat to the pipeline from landslide movement. A high hazard landslide is defined as an:

- Apparently or possibly active landslides within 5 feet of the proposed pipeline centerline.
- Debris flow source areas or debris flow channel that crosses the proposed pipeline centerline.

Justification: Active landslides that cross the pipeline centerline or that are located proximally to the alignment may have a high potential to adversely affect the pipeline(s), with the apparent potential higher than that for moderate landslide hazard areas.

1.2 Unstable Slopes (Rockfalls)

Rockfall hazards can potentially pose a serious threat to pipeline integrity by undercutting and exposing the pipe (in the event that material flows out from underneath the pipeline), or by physically impacting the pipe either through direct contact (for exposed or surface pipes) or through energy propagated downward from the surface (for buried pipelines).

The potential for rockfall hazards to impact a pipeline is difficult to evaluate in a meaningful way from only a desktop assessment. An evaluation of potential rockfall areas in the field is critical to assess possible source areas and runout zones relative to proposed infrastructure. Thus, we have opted not to develop a hazard classification breakdown for rockfalls for this phase of assessment, but rather to treat all identified potential rockfalls areas as containing an undefined threat level.

1.3 Seismic (Ground Shaking)

Strong ground shaking from large earthquakes can potentially strain and damage pipelines as a result of lateral and vertical ground movements, or accelerations from seismic wave propagation (O’Rourke and Liu 1999, 2012).

The potential hazard from earthquake wave propagation is commonly measured by the ground shaking parameter of peak horizontal ground acceleration (PGA), expressed as a percentage of the Earth's gravitational acceleration (g). Earthquake strong ground shaking may also trigger liquefaction and lateral spreading of saturated soil (discussed in Section 1.3), as well as landslides.

We developed general PGA thresholds to characterize low, moderate, and high ground shaking hazards based on empirical correlations between ground motions and reported damage (e.g., Wald et al. 1999). These PGA thresholds correspond with seismic hazard mapping developed by the USGS for ground motions having a 10-percent probability of exceedance in 50 years, which represents a return period of 475 years (Petersen et al. 2014).

Our seismic ground shaking hazard classifications are as follows:

Low Hazard: PGA <0.15 g

Moderate Hazard: PGA 0.15 g to 0.25 g

High Hazard: PGA >0.25 g

Justification: Empirical correlations of potential damage related to ground motions indicate that light damage to engineered surface structures generally occurs in the acceleration range of 0.09 g to 0.18 g; moderate damage occurs in the acceleration range of about 0.18 g to 0.34 g; and moderate to severe damage occurs at accelerations from 0.34 g to 1.24+ g (e.g., Wald et al. 1999). With these correlations, we conservatively selected our hazard classification criteria listed above to highlight areas where corresponding PGA values suggest there may be elevated potential for earthquake shaking to affect a pipeline.

1.4 Seismic (Liquefaction)

Liquefaction involves the transformation of a granular material from a solid to a liquefied state as a result of increased pore-water pressure and reduced effective stress (Youd et al. 2001). Seismic liquefaction typically occurs when loose to moderately dense granular soils with poor drainage such as silty sands, or sands and gravels containing seams of impermeable sediment, are saturated during strong ground shaking events (Youd et al. 2001). Liquefaction of soils involving a pipeline can potentially result in pipe strain or rupture from settlement, heave (buoyancy), and/or lateral displacements. Mass movements, including permanent ground deformation, may also develop as a result of lateral spreading, which occurs when liquefied ground cannot support even shallow slope gradients such that liquefied material flows downslope (O'Rourke and Liu 1999, 2012).

Our liquefaction hazard classifications are as follows:

Low Hazard: Potential liquefaction conditions present in areas where PGA is <0.1 g.

Moderate Hazard: Potential liquefaction conditions present in areas where PGA is 0.1 g to 0.2 g.

High Hazard: Potential liquefaction conditions present in areas where PGA is >0.2 g.

Justification: Liquefaction occurrence is primarily dependent on the presence of loose to moderately dense granular soils with poor drainage such as silty sands, or sands and gravels containing seams of impermeable sediment, that may be frequently or permanently saturated at or near the ground surface and subject to strong ground shaking (Youd et al. 2001). In the absence of site-specific soil, groundwater, and seismic hazard characterization, it is practical to assign qualitative soil liquefaction hazard classifications based on interpreted soil types, groundwater conditions, and published PGA levels (Petersen et al. 2014).

Note: We use slightly lower PGA threshold values to define low, moderate, and high liquefaction hazards than those used to define ground shaking hazards because we assume the effects on a pipeline from liquefaction would be greater than the effects from ground shaking alone. We make this assumption because pipelines tend to have lower rates of damage from ground shaking than from permanent ground deformation as a result of liquefaction-related phenomena (O'Rourke and Liu 1999, 2012).

1.5 Seismic (Surface Fault Rupture)

Surface fault rupture from earthquakes causes permanent ground deformation that induces tensile and compressional forces on pipelines, which have resulted in many pipeline breaks (e.g., rupture, buckling) from fault movement during past earthquakes (O'Rourke and Liu 1999, 2012).

Our fault rupture hazard classifications, which apply to faults that extend into the area 500 feet from the proposed pipeline alignment, are as follows:

Low Hazard

- Faults and fault zones that are mapped by the USGS (2018) as Class B[3] faults and fault zones.
- Faults and fault zones that are reported as active during the Quaternary, but with no information as to age of most recent fault displacement or slip-rate.
- Faults and fault zones with latest movement between 130,000 and 750,000 years ago and slip-rates less than 0.2 millimeter per year (mm/yr).
- Faults and fault zones active during the Quaternary with latest movement >750,000 years ago and slip-rates less than 1 mm/yr.

Justification: Low hazard faults represent faults and fault zones that either appear to be inactive or are considered to have a very low probability of rupturing during the lifetime of the pipeline system.

Moderate Hazard

- Faults and fault zones with latest movement between 15,000 and 130,000 years ago and slip-rates less than 0.2 mm/yr.
- Faults and fault zones with latest movement between 130,000 and 750,000 years ago and slip-rates of 0.2 to 1 mm/yr.
- Faults and fault zones active in the Quaternary with latest movement >750,000 years ago and slip-rates between 1 to 5 mm/yr.

[3]*Class B* faults are defined by the USGS (2006) as "Geologic evidence demonstrates the existence of a fault or suggests Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C [insufficient evidence] but not strong enough to assign it to Class A [demonstrable evidence]."

- Unmapped geomorphic lineaments[4] that do not appear to displace mapped Quaternary deposits or Holocene-aged geomorphic features and deposits.

Justification: Moderate hazard faults represent potentially active faults and fault zones considered to have a higher probability of future displacement than faults identified as low hazards, but a lower probability of displacement than those identified as high hazards, based on fault data compiled by the USGS (2018). Lineaments identified from the available LiDAR data and/or aerial imagery that do not appear to displace mapped Quaternary deposits or Holocene-aged (<12,000 years) geomorphic features and deposits (e.g., stream terraces) are less likely to be active faults than those that do, yet there is uncertainty regarding their origin, age, and hazard potential.

High Hazard

- Faults and fault zones with latest movement <15,000 years ago (any slip rate).
- Faults and fault zones with latest movement between 15,000 and 130,000 years ago and slip-rates greater than 0.2 mm/yr.
- Faults and fault zones with latest movement between 130,000 and 750,000 years ago and slip-rates greater than 1 mm/yr.
- Faults and fault zones active in the Quaternary with latest movement >750,000 years ago and slip-rates greater than 5 mm/yr.
- Unmapped geomorphic lineaments that appear to displace mapped Quaternary deposits or Holocene-aged geomorphic features and deposits.

Justification: High hazard faults represent potentially active faults and fault zones that have the highest probability of future displacement because these features have either reportedly experienced movement in the past 15,000 years or have relatively high slip-rates for their reported age. Lineaments identified from the available LiDAR data and/or aerial imagery that appear to displace mapped Quaternary deposits or Holocene-aged geomorphic features and deposits are more likely to be active faults than those that do not; thus, there is greater uncertainty regarding their hazard potential.

1.6 Subsidence (Karst)

Karst generally refers to topography and features that typically form as a result of dissolution of carbonate rocks such as limestone and dolomite.[5] Common karst features observed in karst topography include sinkholes, ridgetop ponds, caves, disappearing streams (i.e., sinks), and reappearing streams (i.e., springs) that are often interrelated through complex subsurface drainage networks.

Karst processes that mainly result in potential hazards to pipelines involve the formation of sinkholes. Three types of sinkholes commonly form from karst processes (after Tihansky 1999):

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[4] *Lineaments* are linear geomorphic features of regional extent that may represent previously unrecognized faults that have ruptured the ground surface. Lineaments are not always indicative of active faulting and may otherwise be related to structural joints, bedding planes, or magmatic dikes (as examples).
[5] Karst-like features that form from dissolution of non-carbonate evaporites such as gypsum and salt, or that form from erosion of non-carbonate rocks such as sandstone, are often referred to as *pseudokarst.* In the strictest definition, karst refers to dissolution of carbonate rocks such as limestone and dolomite.

Dissolution: A process by which surface drainage dissolves carbonate bedrock from the surface-down, forming shallow depressions that may fill with sediment or ponded water. Dissolution sinkholes develop very slowly and typically have little impact on human activity.

Cover-subsidence: A process by which overlying granular sediments settle or erode into cavities formed by dissolution of the carbonate bedrock below, causing gradual down-warping at the surface. Cover-subsidence sinkholes may develop over months or years and are capable of causing damage to surface facilities.

Cover-collapse: A process that results in abrupt formation of sinkholes that can cause catastrophic damage to surface facilities. Cover-collapse sinkholes form when an underground cavity expands upward due to gradual dissolution and erosion until the overlying materials fail suddenly and collapse into the cavity within minutes or hours.

Although dissolution sinkholes typically have little impact on human activity, they are often indistinguishable from the more hazardous cover-subsidence and cover-collapse sinkholes based on surface expression alone. Therefore, we assume that all possible sinkholes or potentially hazardous karst features identified in the vicinity of the pipeline alignment are either the result of, or are indicative of, ongoing cover-subsidence or cover-collapse processes.

Our karst subsidence hazard classifications are as follows:

<u>Low Hazard</u>

- Areas where carbonate bedrock or evaporites are reported to be present at or near the ground surface and no potentially hazardous karst features were identified within 500 feet of the proposed pipeline centerline based on the available resources.
- Areas where karst features may occur, but where the distribution of karst features are reported and/or appear to be limited relative to the pipeline alignment; and no potentially hazardous karst features were identified within 500 feet the proposed pipeline centerline based on the available resources.

Justification: The occurrence of karst sinkholes and related features is primarily dependent on the presence of carbonate rocks or evaporites at or near the ground surface (Weary and Doctor 2014). The occurrence of carbonate rocks or evaporites, or a relatively limited distribution of karst features, suggests that conditions suitable for karst development may be present along the pipeline alignment, but potentially hazardous karst features do not appear to be prevalent. Therefore, in the absence of potentially hazardous karst features within 500 feet of the pipeline alignment, we classify these areas as low hazards.

<u>Moderate Hazard</u>

- Potentially hazardous karst features identified between 200 and 500 feet from the proposed pipeline centerline.
- Areas where the distribution of karst features are reported and/or observed to be prevalent relative to the proposed pipeline centerline, but an absence of potentially hazardous karst features within 200 feet of the proposed pipeline centerline can be confidently observed based on the available resources.

Justification: Moderate hazard karst areas represent areas where potentially hazardous karst features and processes appear more likely to impact a pipeline than low hazard karst areas based on the proximity and/or observed prevalence of karst features relative to the pipeline.

High Hazard

- Potentially hazardous karst features identified within 200 feet of the proposed pipeline centerline.
- Areas where the distribution of karst features are reported and/or observed to be prevalent relative to the proposed pipeline centerline, but an absence of potentially hazardous karst features within 200 feet of the proposed pipeline centerline cannot be confidently observed based on the available resources.

Justification: High hazard karst areas represent areas where potentially hazardous karst features and processes appear most likely to impact a pipeline based on their close proximity to the pipeline; or there is greater uncertainty regarding the occurrence of karst features within 200 feet of the pipeline in areas where karst features are reported and/or observed to be prevalent.

1.7 Subsidence (Underground Mine)

Collapse or subsidence of underground voids left by underground mining can produce sinkholes similar to those produced by karst. These sinkholes can result from collapse of overlying overburden into a mine or mine related feature (such as air shafts), or the gradual or sudden collapse of the mine itself.

Our underground mine subsidence hazard classifications are as follows:

Low Hazard

- Areas where underground mines are reported to be relatively common in the vicinity of the proposed pipeline centerline, but no evidence of underground mines, related features, or surface subsidence was identified within 500 feet of the proposed pipeline centerline based on the available resources.

Justification: In evaluating potential subsidence from underground mines, available references may range from well-located and well-defined maps of mining operations to poorly-located point data. The mapped extents of underground mines may be well-defined, incomplete, or unavailable. Low hazard mine subsidence areas are intended to highlight areas where regional evidence of underground mining suggests there is greater potential for undocumented mine openings to exist beneath the pipeline, but no evidence of underground mines, mining features, or surface subsidence could be identified within 500 feet of the pipeline based on the available resources.

Moderate Hazard

- Areas within 200 and 500 feet of underground mines and/or related features with no evidence of mine-related subsidence.

Justification: As discussed above in the low hazard section, maps of underground mines may be well-defined, incomplete, or unavailable. Areas in close proximity to mapped underground mines are more likely to be underlain by undocumented underground mine features. In addition, subsidence associated with underground mines may also affect the area outside the limits of the mapped mine area, depending on the severity and extent of the subsidence.

High Hazard

- Areas within 200 feet of underground mines and/or related features with no evidence of mine-related subsidence.
- Areas where underground mines and/or related features are reported to occur within 500 feet of the proposed pipeline centerline and there is evidence of mine-related subsidence.
- Areas within 500 feet of the proposed pipeline centerline where there is predicted future subsidence based on ongoing or planned mining activities.

Justification: As discussed in the previous sections, areas underlain by underground mines have the highest probability of experiencing mine related subsidence, and maps of underground mines may be well-defined, incomplete, or unavailable. Subsidence from underground mines may affect areas that are proximal to an underground mine. Therefore, we consider these conditions to be high underground mine subsidence hazards due to their close proximity to the pipeline and/or history of mine-related subsidence proximal to the pipeline.

1.8 Subsidence (Fluid Withdrawal)

Subsidence from fluid withdrawal can cause permanent ground deformation that may stress pipelines and ultimately lead to pipe rupture. Noticeable or measurable fluid withdrawal subsidence occurs through withdrawal and drawdown of underground fluids in combination with geologic conditions favorable to subsidence (Poland 1984). Typically, fluid withdrawal subsidence occurs when the volume of fluids being removed from a subsurface aquifer is greater than the volume of fluids recharging the aquifer, and when soil or bedrock within the aquifer is compressible (Galloway and Riley 1999).

In most cases, fluid withdrawal subsidence occurs slowly over a large area, with little differential movement within the subsiding areas. In some instances, scarps, fissures, and/or sinkholes may form in response to differential movement within subsiding areas, or from rapid surface subsidence or collapse (e.g., ALSG 2007; Paine et al. 2009, 2012).

Our fluid withdrawal subsidence hazard classifications are as follows:

Low Hazard

- Areas where oil and gas resources exist (e.g., shale plays, tight gas plays, etc.), but where extraction may or may not be presently occurring.
- Areas where major groundwater aquifers exist, but where groundwater depletion is not reported.

Justification: Areas underlain by potential oil and gas or groundwater resources are areas where fluid withdrawal may currently be occurring, or where it could occur in the future. Current or future planned activities in such regions may be unknown or poorly constrained in terms of location or could be undocumented altogether. As such, although these areas are not known to currently pose a threat for ground subsidence related to fluid withdrawal, it is possible undocumented hazards could exist, or that future activities in these areas could pose a future threat.

Moderate Hazard

- Areas that contain well fields or wells for oil and gas exploration and development within 1,000 feet of the pipeline.
- Areas with reported groundwater depletion, but with no reports of fluid withdrawal related ground subsidence.

Justification: Pumping of oil and gas or groundwater from subsurface aquifers is an essential precondition for fluid withdrawal subsidence. However, in most instances, pumping of underground fluids is not associated with noticeable or measurable subsidence because the local geologic conditions are not susceptible to subsidence, because not enough fluid withdrawal has occurred, or because the rate of withdrawal is too low. We have classified areas where fluid withdrawal is likely occurring with no reports found of fluid withdrawal subsidence (at the time of this assessment) as moderate potential fluid withdrawal subsidence hazard areas. While subsidence could potentially occur in these areas, subsidence either is not occurring, is too small in magnitude to have been widely reported or is located in too remote of an area to have been widely noticed.

High Hazard

- Areas that contain well fields or wells for oil and gas exploration and development within 1,000 feet of the pipeline or areas with reported groundwater depletion, where ground subsidence has been reported.
- Areas of reported subsidence may or may not correspond to areas of damaged infrastructure or areas with significant evidence of differential ground displacement, such as fissures or faults.

Justification: Areas with known or probable fluid withdrawal subsidence represent areas where this subsidence could potentially affect a pipeline. In densely populated areas, a lack of reports concerning damage resulting from this subsidence could indicate that the subsidence is relatively minor and is unlikely to significantly affect a pipeline. Conversely, in rural or remote areas, a lack of reports concerning damage could simply indicate that the area is too sparsely populated to have experienced widespread damage. We have classified these areas as high hazard potential fluid withdrawal subsidence areas because they represent locations where a pipeline could be potentially affected.

1.8 Hydrotechnical Hazards (Waterbody Crossings)

A hydrotechnical review of waterbody crossings focuses potential hazards to a pipeline related to fluvial geomorphic erosion and scour processes. This review is often limited by project-specific data, if available, and the quality of publicly available resources including LiDAR data and/or aerial imagery. River and stream channels undergo fluvial geomorphic processes driven by water conveyance that modify channel geometry over time and thereby can pose a threat to pipeline integrity. Channels geomorphic evolution covers a wide range of processes of which are driven by vertical scour/degradation and deposition/aggradation, as well as horizontal bank erosion and lateral channel migration. These specific erosional processes can scour down to the pipeline or erode through channel banks to expose pipeline sagbends.

To classify the potential threat to the proposed pipeline from these fluvial geomorphic processes at river, stream and other drainage crossings, our hydrotechnical hazard classifications are as follows:

Low Hazard

- Waterbodies having minimal observed or future potential for vertical degradation of the channel bed and low lateral erosion of the banks.

Justification: Waterbodies without observable sediment transport processes generally have a lower likelihood of experiencing fluvial geomorphic processes that would experience scour in the bed down to the pipe depth. Low hazard crossings are more likely to be noted as having more stability through increased vegetation both in the channel bed and on the banks, and through local geology restricting erosion. Headcutting processes may still present in a low hazard environment that might not otherwise be visibly apparent in a desktop review.

Moderate Hazard

- Waterbodies having observed or future potential for active vertical aggradation/degradation of the channel bed and/or some visible bank erosion.

Justification: Waterbodies with observable sediment transport processes have a greater potential to experience fluvial geomorphic processes that could scour in the bed down to the pipe depth. Moderate hazard crossings are more likely to have an active channel where aggradation or degradation of the channel bed is visible from a desktop review; however, the specific channel erosion or depositional trends are unknown and can change as channels sort through and balance sediment loads. Moderate hazard channels also may experience some bank erosion; however, active and larger scale lateral migration is typically not observed.

High Hazard

- Waterbodies having observed or future potential for more dynamic riverine processes with active vertical aggradation/degradation of the channel bed and potentially active lateral migration of the main channel and banks throughout, and in some situations beyond the current floodplain.

Justification: Waterbodies with observable sediment transport processes in combination with potential for lateral migration have a greater potential to experience geomorphic processes that could scour in the bed down to the pipe depth. Likewise, the main channel of such waterbodies could migrate and the banks erode laterally through or beyond the current floodplain to expose pipeline sagbends or extended portions of the pipeline buried through the floodplain. The high hazard crossing designation is given for channels with this more dynamic and/or combined threat potential. High hazard crossings are more frequently associated with dynamic geomorphic conditions, higher peak discharge systems, and with correspondingly larger floodplains.

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Table A-1: Geohazard Classification Criteria

Hazard Type		Hazard Classification: Low	Hazard Classification: Moderate	Hazard Classification: High	Comment
Unstable Slopes (Landslides)		- Dormant or relict landslide crossed by or within 20 feet of a proposed pipeline centerline with low potential for renewed activity.	- Active or recently active landslide with geomorphic or instrumental evidence of disturbance within 5 to 20 feet of the proposed pipeline centerline.	- Apparently or possibly active landslides within 5 feet of the proposed pipeline centerline.	
		- Landslide (of any age) located between 20 and 100 feet of the proposed pipeline centerline. - Active or recently active landslide that has been mitigated or repaired, which shows no signs of new ground movement post-repair.	- Debris flow where the run-out/depositional area is crossed by a proposed pipeline centerline.	- Debris flow source areas or debris flow channel that crosses the proposed pipeline centerline.	
Unstable Slopes (Rockfalls)		-	-	-	All identified potential rockfalls areas were classified as an undefined threat level until more a detailed assessment (i.e., field) can be completed.
Seismic (Ground Shaking)		- Areas with < 0.15 g peak ground acceleration (PGA)	- Areas with 0.15 g to 0.25 g PGA	- Areas with > 0.25 g PGA	Assuming probabilistic seismic hazard ground shaking risk level of 10% probability of exceedance in a 50-year period (475-year return period).
Seismic (Liquefaction)		- Potential liquefaction conditions present in areas where PGA is <0.1 g.	- Potential liquefaction conditions present in areas where PGA is 0.1 g to 0.2 g.	- Potential liquefaction conditions present in areas where PGA is >0.2 g.	Assuming probabilistic seismic hazard ground shaking risk level of 10% probability of exceedance in a 50-year period (475-year return period) combined with interpretations of nature, age, and saturation of soil.
Surface Fault Rupture: Seismic	**Age of Fault (years)**	Slip Rate (mm/year)			
	<15,000	-	-	Any Rate	
	15,000 – 130,000	-	< 0.2	≥ 0.2	
	130,000 – 750,000	< 0.2	0.2 – 1.0	> 1.0	
	>750,000	< 1.0	1.0 – 5.0	> 5.0	
	N/A	- Faults and fault zones that are mapped by the USGS (2018) as Class B faults and fault zones. - Faults reported as active within the Quaternary, but with no information as to age of most recent movement or slip-rate	- Unmapped geomorphic lineaments that do not appear to displace mapped Quaternary deposits, or Holocene-aged geomorphic features and deposits.	- Unmapped geomorphic lineaments that appear to displace mapped Quaternary deposits, or Holocene-aged geomorphic features and deposits.	
Subsidence (Karst)		- Areas where carbonate bedrock or evaporites are reported to be present at or near the ground surface and no potentially hazardous karst features were identified within 500 feet of the proposed pipeline centerline based on the available resources.	- Potentially hazardous karst features identified between 200 and 500 feet from the proposed pipeline centerline.	- Potentially hazardous karst features identified within 200 feet of the proposed pipeline centerline.	
		- Areas where karst features may occur, but where the distribution of karst features are reported and/or appear to be limited relative to the pipeline alignment; and no potentially hazardous karst features were identified	- Areas where the distribution of karst features are reported and/or observed to be prevalent relative to the proposed pipeline centerline, but an absence of potentially hazardous karst features within 200 feet of	- Areas where the distribution of karst features are reported and/or observed to be prevalent relative to the proposed pipeline centerline, but an absence of potentially hazardous karst features within 200 feet of	

Hazard Type	Hazard Classification			Comment
	Low	**Moderate**	**High**	
	within 500 feet the proposed pipeline centerline based on the available resources.	the proposed pipeline centerline can be confidently observed based on the available resources.	the proposed pipeline centerline cannot be confidently observed based on the available resources.	
Subsidence (Underground Mine)	- Areas where underground mines are reported to be relatively common in the vicinity of the proposed pipeline centerline, but no evidence of underground mines, related features, or surface subsidence was identified within 500 feet of the proposed pipeline centerline based on the available resources.	- Areas within 200 and 500 feet of underground mines and/or related features with no evidence of mine-related subsidence.	- Areas within 200 feet of underground mines and/or related features with no evidence of mine-related subsidence. - Areas where underground mines and/or related features are reported to occur within 500 feet of the proposed pipeline centerline and there is evidence of mine-related subsidence. - Areas within 500 feet of the proposed pipeline centerline where there is predicted future subsidence based on ongoing or planned mining activities.	
Subsidence (Fluid Withdrawal)	- Areas where oil and gas resources exist (e.g., shale plays, tight gas plays, etc.), but where extraction may or may not be presently occurring.	- Areas that contain well fields or wells for oil and gas exploration and development within 1,000 feet of the pipeline.	- Areas that contain well fields or wells for oil and gas exploration and development within 1,000 feet of the pipeline or areas with reported groundwater depletion, where ground subsidence has been reported.	
	- Areas where major groundwater aquifers exist, but where groundwater depletion is not reported.	- Areas with reported groundwater depletion, but with no reports of fluid withdrawal related ground subsidence.	- Areas of reported subsidence may or may not correspond to areas of damaged infrastructure or areas with significant evidence of differential ground displacement, such as fissures or faults.	
Hydrotechnical Hazards – **Watercourse Crossing Erosion and Scour**	- Waterbodies having minimal observed or future potential for vertical degradation of the channel bed and low lateral erosion of the banks.	- Waterbodies having observed or future potential for active vertical aggradation/degradation of the channel bed and/or some visible bank erosion.	- Waterbodies having observed or future potential for more dynamic riverine processes with active vertical aggradation/degradation of the channel bed and potentially active lateral migration of the main channel and banks throughout, and in some situations beyond the current floodplain.	

102 Magma Heights – P.O. Box 1944
Superior, AZ 85173
Tel.: 520.689.9374
Fax: 520.689.9304

20 May 2020

Via email to: mary.rasmussen@usda.gov

Mary Rasmussen
US Forest Service
Supervisor's Office
2324E McDowell Road
Phoenix, AZ 85006-2496

Subject: Resolution Copper Mining, LLC – Mine Plan of Operations and Land Exchange – Response to Action Item GS-15 (Geology, Subsidence, Seismicity)

Dear Ms. Rasmussen,

Enclosed for your review and consideration and in response to Geo-Subsidence/Seismicity Action Item # GS-15 please see the information below:

Action Item GS-15: *Provide updated information for the northern Skunk Camp pipeline corridor, including: GIS alignment; a summary of changes between the design or route analyzed in the DEIS and the current design or route; any updates to the pipeline protection plan; and clarification of any pertinent standards and guidelines used for design and construction of the pipeline(s), especially as they relate to seismic events or land movement.*

RC Response: The attached technical report by Golder (2020) titled "Resolution Copper Skunk Camp Pipelines, Pipeline Protection and Integrity Plan" contained in attachment 1 contains detailed information on the pipeline project components and route, a failure modes analysis and geohazards assessment including seismic or land movement, measures for prevention and detection of failures and design criteria aligned to best practice standards, codes and federal regulations.

Should you have any questions or require further information please do not hesitate to contact me.

Sincerely,

Vicky Peacey
Senior Manager, Permitting and Approvals; Resolution Copper Company, as Manager of Resolution Copper Mining LLC

Attachments:

Attachment 1 – Golder (2020), Resolution Copper Skunk Camp Pipelines, Pipeline Protection and Integrity Plan.