Hatfield
CONSULTANTS

MEMO

Date:	22 April 2016	HCP Ref No.: CZN7932-NV
From:	John Wilcockson (Hatfield Consultants)	
To:	David Harpley (Canadian Zinc Corp)	
Subject:	Proposed all-season road, responses to information requests	

Canadian Zinc Corp (CZN) has applied for a permit to build and operate an all season road linking the Prairie Creek Mine to Highway 7, just east of the community of Nahanni Butte, NWT. This memo responds to some of the information requests (IRs) posed to CZN by environmental assessment (EA) interveners as well as the Mackenzie Valley Environmental Impact Review Board (MVEIRB). All IRs considered here relate to the aquatic biology of streams either crossed or parallel to the all-season road.

1.0 PARKS CANADA IR # 21 – NOISE

Preamble

(Please note that much of the text in this preamble was copied from the responses to the adequacy review which were presented in the DAR Addendum; however, much of the text is applicable to IR#21, therefore has been re-stated here. Also note that this information was not referred to by Parks Canada in their IR)

We reviewed several documents in order to acquire information about road noise effects on fish:

- The Northern Land use guidelines; access: roads and trails Volume 5 (AANDC 2015);
- Standard specifications for highway construction in British Columbia (BCMOT 2015); and
- The environmental impact statement for construction of the Inuvik to Tuktoyaktuk Highway, NWT, (Kiggiak-EBA Consulting Ltd, 2011).

None of these documents identified traffic noise as a concern to fish. Potential impacts of noise, however, were noted related to percussion effects due to pile driving and blasting. A Canada/Inuvialuit Fisheries Joint Management Committee Report (Stewart 2003) assessed potential effects of dump trucks carrying crushed rock over the Mackenzie River in winter. This report assessed potential impacts related to a large volume of heavy traffic over the river ice. The concern was that noise from these trucks might result in impacts to fish. The study concluded that the noise from the trucks was unlikely to generate sound pressure levels under the ice sufficient to physically damage fish, or to elicit startle or alarm responses (Stewart 2003). However, it stated that the intensity of noise would be sufficient to cause some species that are more sensitive to noise, namely minnows and suckers in the Mackenzie Delta, to avoid the area. Given that the Prairie Creek Mine traffic or construction vehicles will be driving on roads some distance from streams, or driving over structures not in direct contact with water, it is unlikely that noise would be any greater than that reported in the Joint study. The report also indicates that fish become acclimated to continuous sound levels, even when they are very high, unless there is an abrupt change in sound intensity (Stewart 2003).

A recent study showed that blacktail shiner (*Cyprinella venusta*) have difficulty communicating with each other over ambient traffic noise (Holt and Johnson 2015). This study was done on flat (i.e., quiet water) on species that have specialized sensitive hearing structures, required for communication. It is unlikely that the species living in streams adjacent to the Prairie Creek all-season access road, normally in water with riffle morphology, would be affected similarly.

Sections of Funeral Creek are proximal to the proposed all-season road, and the resident fish include bull trout, a salmonid species. Salmonids are known to have simple, non-specialized, relatively insensitive hearing structures (Popper and Hastings 2009, Stewart 2003). The natural noise of riffles and cascades in Funeral Creek would also act to mask the incremental noise of trucks. Furthermore, entrained bubbles as a result of the riffles and cascades in Funeral Creek would act to attenuate any noise produced by passing trucks.

Funeral Creek likely freezes to the bottom in winter, with the exception of perhaps a few deep pools. Only developing bull trout embryos are likely to be present. Therefore, it is significant that research reports “no effects on eggs or fry [of species tested] from noise louder than trucks” (Section 11.4.2 of the DAR).

IR#21 Point 1:

The information evaluating potential negative effects of noise on fish needs to be defined in terms of the specific vehicles that will use the road and the noise levels that these specific vehicles, or classes of vehicles, will produce.

Response:

The Developer’s Assessment Report (DAR 2015) indicated that vehicles using the road would consist of vehicles with a noise intensity of ~ 99 dBA in air. In addition, the DAR stated that at 0.5 km from the road, the noise intensity is expected to be reduced to 35 dBA; which is comparable to the level between normal speech and a whisper (Golder 2010 as cited in the DAR 2015).

A document produced by Tetra Tech EBA Inc., (2005) for CZN in reply to Board IRs 32 and 33 lists the heavy equipment that will be required during construction and operation of the all season road, with their estimated associated noise intensities (Table 1).

The sound intensities provided above are for sound transmission in air, and will be different from the associated intensities under water in adjacent creeks. Much of the sound underwater will come directly from the roadbed via the ground to the adjacent creek. However, the data in Table 1 indicate that dump and haul trucks will likely generate the greatest noise.

Estimates of the probable noise intensity underwater adjacent to the road could not be found in available scientific literature. However, given the argument provided in the preamble, we believe the potential for significant effects is low. Also, it is unlikely that the noise intensity would be any greater than that generated by the permitted winter road.

Based on the above information, we believe noise levels from the equipment that will use the road will not significantly impact fish in the adjacent streams.

Table 1 Sound level for individual pieces of equipment at defined distances from the source.

Noise Source	Time Period	Sound Intensity (dBA) at Distances from Source			
		15 m	30 m	60 m	120 m
Bulldozer	Road construction only	85	79	73	67
Loader	Road construction only	85	79	73	67
Crane	Road construction only	83	77	71	65
Moving dump truck or haul truck	Road construction and operation	88	82	76	70
Idling dump truck or haul truck	Road construction	65	59	53	47

Notes:

Reference sound level obtained from OMOE Publication NPC-115, contained in the OMOE Model Municipal Noise Control By-Law 1977.

Reference sound levels obtained from US Department of Transportation. Transit Noise and Vibration Impacts Assessment, Chapter 12: Noise and Vibration, 1977.

Reference sound level obtained from British Standards No. 5228, Second Edition, May 1997.

IR#21 Point 2:

Using GIS tools and best available noise thresholds, calculate: i) lengths of the road where noise thresholds have the potential to affect fish and ii) total area of stream habitats that may be impacted by road traffic noise.

Response:

As discussed in the preamble above, existing literature indicates that effects on fish as a result of road traffic noise are negligible. Therefore, quantification of road lengths and areas is not necessary.

IR#21 Point 3:

Define noise effect thresholds along the all season road including those adjacent to bridges and culverts.

Response:

The DAR provided a threshold of 50 to 70 dB-re-1µPa. A review of the original source (USDoT 2004) indicates that this is the threshold for noise detection by fish, not a threshold for effect. However the DAR also reported that several species had been adversely affected at >180 dB-re-1µPa after two hours or less of exposure (DAR 2015). Hasting and Popper (2005) estimated 195 to 200 dB-re-1µPa as the threshold for physical injury to fish.

Due to the different properties of air and water, sound is transmitted differently. Sound is easily transported in water due to the high density and low elasticity of water, causing high sound propagation (Tetra Tech, 2016). As a result, sound travels approximately five times faster in water than air and travels a much greater distance, causing exposure of aquatic organisms to noise vibrations over longer distances (Slabbekoorn et al 2010). As a result, background noise is common in an aquatic system. Travolga (1974) found that sound has to be at least 10 dB greater than background to be detected by fish.

Scholik and Yan (2002) found background levels of 80 dB-re-1µPa in an open water pond with no exposure to anthropogenic disturbances. This study concluded that noise levels lower than ~ 90 dB-re-1µPa would not result in a strong adverse response for fish that are hearing generalists, represented by most species found in the study area. Furthermore, ambient background noise associated with riffles and rapids would likely result in much higher background noise, thus masking most anthropogenic noises.

Bridges will be in direct contact with road traffic, but not the water. Culverts will not be in direct contact with road traffic. Therefore, the ground would reduce the intensity of vibration before it enters the water, making it unlikely that the noise would be greater than observed during the Joint study (Steward 2003).

Therefore, we do not anticipate that the threshold of >180 dB-re-1µPa for impacts on fish will be exceeded in aquatic habitats anywhere along the length of the all season road.

IR#21 Point 4:

Define potential effects of roads on fish to include those potentially resulting from vibrations of the road surfaces especially those adjacent to bridges and culverts.

Response:

As was discussed in the preamble, Steward (2003) indicated that the intensity of the noise produced by highway trucks driving on the frozen Mackenzie River may be sufficient to cause suckers and minnows to display startle or alarm responses. These fish species are hearing specialists and are invariably more sensitive to noise than hearing generalists. Species most often found adjacent to the proposed all-season road, (i.e., bull trout, Arctic grayling and sculpins), are hearing generalists and are therefore much less sensitive to noise. Minnow species and suckers have only been documented in the Tetcela and Grainger Rivers. The road has fish-bearing crossings of these rivers with two and one clear-span bridges, respectively, which will mitigate vibration from vehicles reaching the water surface and transmission to resident fish. In addition, no critical or unique habitat was identified at the crossings, so fish would have the opportunity to move away from noise without any anticipated effects to the populations of these species.

Steward (2003) stated that fish may become acclimated to continuous sound levels of a consistent frequency, even when sound intensities are very high. However, an abrupt change in sound intensity may still cause an adverse response from acclimated fish. These findings are in agreement with those of Knudsen (1992), who observed acclimation of juvenile Atlantic salmon to noise over time. Road traffic sounds from the proposed all-season road would not be abrupt, but instead fish would experience sound intensity that rises and falls as each truck passes.

Therefore, we do not anticipate any impacts of vibrations from roads or bridges on fish.

IR#21 Point 5:

Evaluate if the road noise thresholds could be reduced by reducing traffic speeds.

Response:

Noise and other vibrations from trucks reduce at slower speeds. Information obtained from the USDoT (2016b) for trucks travelling on paved roads indicated that noise (through air) decreases only slightly at slower speeds (Table 2). Note, the lowest maximum noise level listed in Table 2 is for speeds less than 35 mph, which is about 60 kph. Haul trucks on the all season road are unlikely to exceed this speed in proximity to fish-bearing water.

Ground vibration is also a function of the weight of vehicle, softness of the truck's suspension, and smoothness of the road. Of these variables, smoothness of the road generally has the greatest influence on noise coming from road traffic (Al-Hunaidi and Rainer 1991). Soil absorption is an important determinant of vibration attenuation with distance. Dry sand and gravel soils have the highest capability to absorb vibration, while soft clay or peat have the lowest (Hajek et al 2006). Given the evidence presented thus far indicating negligible risk of impact to resident fish, we do not think such measures are necessary, and will present an unnecessary burden on operations with no significant benefit in terms of effects on fish.

Table 2 Noise intensity associated with a truck moving at different speeds.

Speed	Maximum Noise Level (at 50 ft. from Centerline of Travel)
<35 mph	83 dBA
>35 mph	87 dBA
Stationary	85 dBA

IR#21 Point 6:

Identify if measures will be taken to quantify potential effects of road traffic noise on fish populations and if so, outline what experimental design will be used to assess these potential negative effects (e.g., a before-after, control impact design to assess impact).

Response:

Effects on fish from road noise are not anticipated, therefore, no noise monitoring is proposed.

References

Al-Hunaidi M.O. and J.H. Rainer. 1991. Remedial measures for traffic-induced vibrations at a Residential site. Part 1: field tests Canadian Acoustics 19(1) 3-13.

Banner, A. and M. Hyatt. 1973. Effects of noise on eggs and larvae of two estuarine fish. Transactions of the American Fisheries Society 102:134-136.

Blaxter, J.H.S. and D.E. Hoss. 1981. Startle response in herring *Clupea harengus*: The effect of sound stimulus. Journal of the Marine Biological Association of the United Kingdom. 61:871-880.

Caltrans 2004. Fisheries and Hydroacoustic Monitoring Program Compliance Report for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project. Prepared by Strategic Environmental Consulting, Inc. and Illingworth & Rodkin, Inc. June.

[CZN] Canadian Zinc Corporation. 2015. Developer's Assessment Report All Season Road Project Prairie Creek Mine. Main Report (Volume 1 of 3). Submitted by Canadian Zinc Corporation to the Mackenzie Valley Review Board in support of Environmental Assessment of Prairie Creek Mine EA 14-15-01. April, 2015.

Golder (Golder Associates Ltd.). 2010. Vegetation and Wildlife Assessment Report, Prairie Creek Mine, Northwest Territories. Prepared for Canadian Zinc Corporation.118 pp.

Hajek JJ, Blaney CT, Hein DK. 2006. Mitigation of Highway Traffic-Induced Vibration, Session on Quiet Pavements: Reducing Noise and Vibration 2006 Annual Conference of the Transportation Association of Canada, Charlottetown, Prince Edward Island.

Hastings MC, Popper AN, Finneran JJ, Lanford PJ. 1996. Effect of low frequency underwater sound on hair cells of the inner ear and lateral line of the teleost fish *Astronotus ocellatus*. J. Acoust. Soc. Am. 99, 1759-1766.

Hastings MC, Popper AN. 2005. Effects of Sound on Fish. California Department of Transportation Contract 43A0139 Task Order, 1, pp. 72.

[Hatfield] Hatfield Consultants Ltd. 2015. All-season road – response to adequacy review – fish and fish habitat. Prepared for Canadian Zinc Corporation.

Holt DE, Johnston CE. 2015. Traffic noise masks acoustic signals of freshwater stream fish. Biological Conservation, 187:27-33.

Keevin TM, Hempen GL, Schaeffer DJ. 1997. Use of a bubble curtain to reduce fish mortality during explosive demolition of Locks and Dam 26, Mississippi River. In Proceedings of the Twenty-third Annual Conference on Explosives and Blasting Technique, Las Vegas, Nevada, International Society of Explosive Engineers, Cleveland, OH, pp. 197-206.

Knudsen FR. 1992. Awareness reactions and avoidance responses to sound in juvenile Atlantic salmon, (Sulmo salar L.) Journal of Fish Biology. 40:523-534.

Mainstream Aquatics Ltd. 2005. Review of ice road travel noise-related impacts on fish – Jericho Diamond Project. Prepared for Jericho Diamond Corporation. Report No. 05008A: 11 pp. Tetra Tech 2005

Popper AN, Hastings MC. 2009. Review paper: the effects of anthropogenic sources of sound on fishes, J of Fish Biol, 75:455-489.

Scholik AR, Yan HY. 2002. Effects of boat engine noise on the auditory sensitivity of the fathead minnow, *Pimephales promelas*. Environmental Biology of Fishes 63: 203-209.

Slabbekoorn H, Bouton N, Opzeeland IV, Coers A, Cate CT, & Popper AN. 2010. A noisy spring: the impact of globally rising underwater sound levels on fish. Elsevier Ltd. 10:1016.

Stewart DB. 2003. Possible Impacts on Overwintering Fish of Trucking Granular Materials Over Lake and River Ice in the Mackenzie Delta Area. Canada/Inuvialuit Fisheries Joint Management Committee Report 2003-1: v + 12 p.

Tetra Tech. 2016. Response to MVRB IRs 32 and 33 – Noise Assessment. Prepared for Canadian Zinc Corporation.

Travolga WN. 1974. Signal/noise ratio and the critical band in fishes. Journal of the Acoustical Society of America 55:1323-1333.

Williams MT, Moulton VD, Richardson WJ, Blackwell SB. 2004. Chapter 3 In: W.J. Richardson and M.T. Williams (eds.). 2004. Monitoring of industrial sounds, seals, and bowhead whales near BP's Northstar oil development, Alaskan Beaufort Sea, 1999–2003. Rep. from LGL Ltd. (King City, Ont.), Greeneridge Sciences Inc. (Santa Barbara, CA) and WEST Inc. (Cheyenne, WY), for BP Exploration (Alaska) Inc., Anchorage, AK.

[US DoT] U.S Department of Transportation Federal Highway Administration 2004. Synthesis of Noise Effects on Wildlife Populations. Publication No. FHWA-HEP-06-016 September 2004.

US DoT. 2016a. Construction Noise Handbook. Accessed April, 2016. http://www.fhwa.dot.gov/environment/noise/construction_noise/handbook/handbook09.cfm.

US DoT. 2016b Highway Traffic and Construction Noise – Problem and Response. Accessed April 2016. http://www.fhwa.dot.gov/environment/noise/regulations_and_guidance/probresp.cfm

2.0 PARKS CANADA IR # 25 – POINT #2 – COLONIZATION OF NEW CHANNEL

Request

Based on knowledge of colonization dynamics of benthos from previously denuded reaches of streams identify the length of time required for benthic macroinvertebrate communities to resemble natural communities [in the new channel, after the Sundog Creek diversion between km 35.5 and 37].

Response:

At KP35.5, CZN proposes to divert Sundog Creek so that it flows away from the proposed all season road and into a former channel. In order to make the former channel the new thalweg, CZN proposes to deepen it.

The stretch of Sundog Creek containing the channel to be diverted tends to be dry between summer and early spring. However, given the observed presence of flowing water upstream and downstream of this stretch in summer, there must be considerable water flow through the coarse alluvial bed material. Colonization of this stretch of creek would be negatively impacted by the loss of surface water flow, as well as bed load movements that likely occur during freshet (May) and especially during heavy rainfall events, which can occur in the summer (July/August), but not always. Recolonization of the stretch would be helped by drift from the upstream, flowing portions of the creek as well as (but likely to a lesser extent) from flying, egg-laying adults (MacKay 1992).

Given that this stretch was (and continues to be) naturally depopulated from periods of bedload movement and periods where the channel is completely dry, it is expected to provide poor benthic invertebrate habitat relative to areas of Sundog Creek upstream and downstream of the stretch under consideration. Therefore, the relative impact on the creek from diverting the creek in this stretch compared to other stretches will be smaller.

We anticipate that use of this section of creek by benthic invertebrates will primarily occur during freshet and end after the channel dries up, thus providing habitat only for approximately two months. A second, much shorter period of inundation would be associated with heavy rain fall events resulting in higher flows and surface water. However, we anticipate that surface flows resulting from rainfall events, which are infrequent, would last for no more than a week. Due to the short period of inundation each year, it is anticipated that limited periphyton communities would develop on the rocks in the reach of interest thus providing only limited sources of food for benthic invertebrates compared to portions of the creek that have flow over longer periods. Rocks with significant periphyton coverage were observed approximately 2 km downstream in a portion of the creek with flowing water in July. Terrestrial (i.e., allochthonous) sources of organic carbon appear to be negligible, given that the creek drains a mountainous area with little vegetation.

We anticipate that the new thalweg should take little time to attain the same level of stability as adjacent natural sections of the creek. Both the new thalweg and natural stretches of creek would experience scour during higher flows. Furthermore, given that the new thalweg is being created in an existing defined, albeit generally former channel, this indicates that the channel was stable when it was last inundated. We anticipate that the habitat in the new thalweg channel will, after one season, approximate the same (poor) benthic invertebrate habitat present in the existing natural dry channel that it will replace. In relation to the reaches of the creek upstream and downstream, the difference in habitat in the new channel compared to the original is considered to be insignificant.

The portion of the existing channel not occupied by the road (in the original thalweg) will provide continued ephemeral aquatic habitat. During freshet and periods of heavy precipitation, the channel is expected to contain surface water fed via subsurface flows. Because the water will be fed from subsurface water, it is not clear whether it would be colonized by drifting invertebrates, however the water would be available to flying, ovipositing adults and crawling invertebrates when wetted. Therefore, as long as invertebrate larvae living in this channel were able to drift out before it dried, the channel would continue to provide additional benthic insect recruitment to Sundog Creek.

The stability of the diversion structure is required to avoid erosion of the all-season road. CZN will monitor and repair the diversion as needed. Therefore, it is likely that the portion of the original channel (with associated habitat) not used by the road will remain during the lifespan of the road.

References

Mackay, R.J., 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. Can. J. Fish. Aquat. Sci. 49:617-628.

3.0 MVEIRB IR # 24 – HABITAT REQUIREMENTS

Request

Please clearly identify where additional information on habitat requirements for each life stage of fish species can be found in the materials provided by CanZinc to date. If it has not been described, please provide the information as requested in the Terms of Reference.

Response:

Unless otherwise cited, information below has been drawn from Minns et al. (2002).

Bull trout

Bull trout are found in Prairie Creek, Casket Creek and Funeral Creek (Hatfield 2015). It has been classified by COSEWIC as a species of Special Concern (SARA 2016) given that its populations can be threatened on a regional basis.

Bull trout typically require clear stream channels that have healthy riparian zones for rearing and spawning. Studies have also found that adults require cold water and will not be found in temperatures greater than 15°C.

Bull trout exhibit two different life-history strategies: migratory and non-migratory. Within the Prairie Creek drainage, it is believed that both life histories exist. Mochnacz et al. (2012) observed both resident populations and populations migrating from the Nahanni River. Individuals have been observed spawning in the smaller tributaries of Prairie Creek in the fall, and it is believed that alevins likely overwinter in the ice-free interstitial areas within the bottom substrates. Monchnacz (2012) has observed resident populations of bull trout in several of the larger tributaries to Prairie Creek, including Funeral Creek.

Both resident and migratory populations at the site use headwater and tributary streams for fall spawning. Spawning areas are typically smaller, cold streams and rivers, with riffle and pool areas that have a close proximity to cover. The spawning substrate is typically cobble (8-32 mm diameter) and gravel containing 22-33 % fine sediment. The spawning depth ranges from 0.18 to 0.54 m with water velocities between 0.12 and 0.66 m/s; this may vary with location and life history. The typical temperature range for spawning is 5 to 9°C. Larger streams also can be used for spawning. Spawning gravels are generally found in areas with groundwater upwelling, which allows for stable temperatures and overwinter flows important for egg incubation. After spawning is complete, migrating adults typically move to larger rivers and major tributaries. The eggs develop in spawning gravels over the winter and fry emerge in spring.

Fry are found amongst cobble, boulders and interstitial habitat in shallow water with velocities lower than 0.10 m/s. Typically, fry are found in shallow depths (up to 15 cm) with an abundance of cover such as submerged vegetation and woody debris.

The young of the year (YOY) are extremely substrate-orientated, with a high dependence on embedded cobble, gravel, boulder with overhanging vegetation and woody debris. YOY will utilize runs, riffles and pools equally, while adults (1 + year old) prefer deep pool areas with sand to pebble substrate. In addition, YOY prefer the channel margins, small side channel and backwater areas, while adults prefer the main channel.

YOY typically utilize pools in the summer, but will move into runs later in the year, and overwinter in pools typically with no overhead cover or surface flow, but with groundwater upwelling and interstitial spaces between gravel and cobble substrates for cover. Typically YOY are associated with small streams for the first two years of life, with adults moving into larger tributaries or lakes.

Bull trout have a slow growth rate, and are typically slow to mature; in addition not all reproductively viable individuals reproduce in consecutive years.

Priairie Creek provides habitat to migratory adults and some overwintering habitat for resident adults. There may also be isolated locations for migratory adult spawning. Funeral and Casket creeks, both major tributaries to Prairie, provide spawning habitat to both resident and migratory adults, as well as rearing habitat for fry and YOY.

Round Whitefish:

Round whitefish are found in Prairie Creek, Tetcela River and Grainger River (Hatfield 2015). They display both lacustrine and riverine life histories.

Spawning can occur in lakes, rivers and clear streams. In the East Arctic region, spawning occurs in late fall (October) in rivers with gravel and cobble substrate that is free of sand with a temperature of ~ 4.5 °C and a depth of 9 m. In the Yukon region, spawning was observed in both fast and slow water, at depths between 70 to 250 cm over substrate of silt, gravel and boulders. The eggs incubate under the ice and hatch in the spring (April and May).

The larvae prefer sand or silt substrates over cobble and gravel and are typically found in backwater areas where the water velocity is zero or only a slight current exists. Lee (1985) found that submergent vegetation is not utilized when present. Instead the larvae were found to use turbidity for cover in most cases; although cobble, boulders and debris, and overhanging vegetation were also used. The larvae will typically migrate downstream to the lower part of the river during their first year; a study in Siberia found that the last few larvae migrated in June. As juveniles mature, they typically migrate to faster and deeper water.

Adult round whitefish will utilize areas with high turbidity if no cover exists, but prefer the following cover types (ordered from most preferred to least preferred): cobble and boulder; undercut banks; overhanging vegetation; debris/deadfall; submergent vegetation; emergent vegetation; and rubble and large gravel. Optimal water velocities were found to range between 0.61 to 0.91 m/s. A study in northern Alaska found that adult whitefish preferred deep pools in large streams that had relatively low velocities (0.17 m/s) with coarse substrate types and undercut banks. Most whitefish mature around the age of 6 to 9 and the oldest fish caught was 12 years old.

The ubiquitous occurrence of cobble substrates in Prairie Creek, Tetcela River and Grainger River provides good habitat for round whitefish.

Arctic Grayling:

Arctic grayling are found in lower Prairie Creek near its confluence with Nahanni River, Sundog Creek, Polje Creek, Tetcela River and Grainger River (Hatfield 2015). Grayling generally prefer streams with low turbidity, however all of the noted streams can be very turbid during high water.

Arctic grayling spawn in the spring (from mid-May to early June) in clear water. Spawning dates may vary with location, but occurs in water temperatures between 7 and 10°C. Adults typically migrate from larger rivers into smaller streams to spawn and require areas with gravels about 2.5 cm in diameter; a percentage of sandy substrate (<15-20 %) has also been found in spawning areas. Spawning has been recorded within riffles and pools in Alaska; with typical surface water velocities of less than 1.4 m/s. Generally, grayling will spawn during the midday to late afternoon period, over a period of 2-3 weeks. After spawning, the adult grayling will migrate back to summer habitat downstream to larger rivers.

The fry will hatch within 8-32 days at a temperature of 5.8-15.5°C; the length of incubation is highly dependent on temperature and may vary with location. The fry will spend three to five days under the substrate. After emerging from the substrate, fry will reside in pools and side channels of the stream approximately 30 and 50 cm in depth. Preferred bottom substrates consist of boulder, cobble, silt and sand, while preferred velocities are less than 0.8 m/s. The fry will initially school together, but within a three week period individuals will begin to display antagonistic behaviour towards each other. Fry remain in their natal stream for up to 15 months; individuals may then remain in their natal stream feeding or move to other areas of the river system.

YOY reside in areas that have gravel, silt and cobble with some sand in slow-moving water of shallow depth. Studies indicated rocks are the most utilized cover, with cut banks, loose gravel, overhanging vegetation and in-stream vegetation and shade used to a lesser extent. YOY have been captured in both silt substrates with depths of 20-80 cm and riffles areas with depths of 20-30 cm. As fish mature, they will move to deeper and faster water in areas that are close to shore, backwater areas, pools or side channels.

Adults show a preference for areas with cobble and gravel and are commonly found over fine grained and coarse substrates, with an avoidance of medium grained substrates. Adults will often use rocks for cover, with a small percentage (14%) using overhanging vegetation, undercut banks, and deadfall. Typically, individuals reside in water with high velocities, 0.61-1.08 m/s, and in deeper depths (1.10-1.52 m); however, individuals can be found in water with velocities up to 1.3 m/s, depths of 23-91 cm. Adult grayling require deep pools for overwintering.

Grayling may mature in as early as two years, or as late as nine years. Once mature, a grayling is likely to spawn every year.

The above noted habitat is common in the listed streams, accounting for the presence of grayling.in spring and summer. However, as flows subside in the fall and winter, few likely survive in the upper reaches of Sundog Creek, including Polje Creek, and those that do are confined to deep pools.

<u>Slimy Sculpin:</u>

Slimy sculpin are ubiquitous in Prairie Creek, Sundog Creek, Tetcela River and Grainger River (Hatfield 2015). The species is typically found in riverine habitat with rocky or gravelly bottoms. The species has a small home range and does not typically migrate. Spawning occurs in spring, typically between May and June, when temperatures are ~3.5°C. Spawning habitat is typically under a rock, ledge or submerged tree root.

The eggs take four weeks to hatch at a temperature of ~8°C. The fry hatch and will remain in the yolk sac for an additional, 3-6 days. The fry will then leave the nest and move to the nursery area. Typically the nursery area is within cobble and boulder substrate, under 13 to 22 cm of water, with a velocity between 0.06 and 0.56 m/s; however, young have been found in deeper water (10-30 cm), with stronger currents (5-40 cm/s).

Adult sculpin in the Arctic appear to prefer clear streams with gravel substrates. In Wisconsin, adults have been found in rubble, boulder, silt, gravel, bedrock and sand substrates, and within areas with dense submerged aquatic plants and fast currents at an average depth of 13 cm depth. Most adults mature after two years, but maturity can occur between 1 and 3 years of age.

Northern Pike:

Northern pike (pike) have been documented in the Tetcela and Grainger Rivers (Hatfield 2015). Pike are ambush predators and require cover such as aquatic plants, tree stumps, and fallen logs. Pike spawn during the spring in the backwaters of rivers, streams, lakes, and marshes that have aquatic vegetation. Preferred spawning areas have submerged vegetation, with temperatures ranging from 4 to 16°C, with little to no current, and in less than 30 cm of water. Eggs are attached to the submerged vegetation, making the presence of macrophytes a highly important factor. Typically, spawning will occur in areas with mud substrate and a vegetation mat.

Northern Pike fry hatch after 12 to 14 days and immediately attach to the submerged vegetation with an adhesive gland on top of their heads. The fry will remain attached to the vegetation until the yolk sac has been absorbed. Fry develop near where they hatched. Nursery habitat consists of dense submerged and emergent vegetation in back eddies or at the mouths of tributary streams. The fry will remain in the spawning area for several weeks.

In the Mackenzie River, YOY will move into slower water and weedy areas of the main river. YOY northern pike were observed in the main river in July, although some remained in the tributary streams. YOY are typically found in depths less than 2 m, over mud and silt substrate with aquatic vegetation for cover.

Adults can be found in large weedy back eddies and mouths of tributaries that have a high abundance of forage fish. Typically these areas are shallow, and have no velocity, substrate consists of mud and silt substrate, and there is aquatic vegetation. Female northern pike mature between 3 and 8 years, while males mature between 2 and 6 years. Northern pike can live to be up to 15 to 26 years old.

Longnose Sucker:

Longnose Sucker have been documented in the Tetcela River (Hatfield 2015). They are typically found in rivers, lakes and streams with clear or turbid water. The longnose sucker is primarily a bottom-dwelling species

Spawning typically occurs between May and June, when water temperatures range from 8-16 °C. Typical spawning habitat is large rocks 10-50 cm in diameter or sand and gravel less than 1 cm in diameter at depths between 15-54 cm and a velocity between 25-100 cm/s. Mating will typically occur during daylight.

Eggs typically hatch after seven days at a water temperature of 17 °C. The fry will remain in the gravel for one to two weeks before emerging from the substrate and moving downstream. During the downstream migration, fry are commonly in fast flowing water or near the surface. Fry were observed to be most abundant in the mouths of fast flowing creeks, but also in shallow pools where available.

After spawning, adult suckers will disperse downstream within the river system or to lakes. YOY and adults are commonly found in slow water such as back eddies or river mouths. Individuals spawn each year after they have reached maturity. Males mature at age 4-9 and females at 6-12. Long-nose sucker is a long-lived species with a maximum age of 28 years.

<u>Lake Chub:</u>

Lake Chub have been observed in the Tetcela River (Hatfield 2015). This species is a widespread cyprinid, and prefers lakes but can frequently be found in riverine habitats. Lake chub is found in both clear and muddy waters and sometimes in large schools.

Spawning has been observed in the South Nahanni River in May. Spawning typically occurs in shallow areas with slow moving water amongst cobble or boulder substrate. Eggs hatch after 10 days at a temperature range of 8-19 °C. Studies indicate that fry can be found among submerged vegetation, while YOY can be found in areas with rocky bottoms. Adults can be found in a variety of habitats ranging from clear streams and tributary mouths to the turbid waters of the Liard River. Studies indicate that Lake Chub use rocks for cover and have been found at stream mouths in water depths of 1 m or less. Lake Chub mature in their third or fourth year and can live up to five years.

<u>Longnose Dace:</u>

Longnose Dace have been observed in the Tetcela River (Hatfield 2015). This species can occur in either clear or turbid water, but prefers turbulent swift-flowing streams with gravel or boulder substrates, with clear pools. This species does not school.

Information is lacking regarding northern populations, but the southern population spawns from May to July; spawning may occur later for the northern populations. Spawning occurs in riffle areas of streams over gravel substrates.

Eggs hatch after 7-10 days at 15.6°C. New hatchlings live in their egg sacs for seven days. The fry will then live pelagically for approximately four months in shallow water along the banks of rivers. After another four months, individuals will then move to faster, deeper water and will eventually become bottom dwellers. YOY are typically found in depths of 10-19 cm and avoid depths below 20 cm.

Adults can typically be found in rocky sections of tributaries in fast currents with boulder, silt and gravel substrates. Occasionally, individuals can be found over mud, clay, bedrock and detrital substrates. Individuals will mature after between two and three years.

References

[Hatfield, 2015] Hatfield Consultants Ltd. 2015. All-season road – response to adequacy review – fish and fish habitat. Prepared for Canadian Zinc Corporation.

Minns CK, Resit JD, & CL Evans. 2002. Life History Characteristics Of Freshwater Fishes Occurring In The Northwest Territories and Nunavut, With Major Emphasis on Riverine Habitat Requirements. Department of Fisheries and Oceans. Canada.

Mochnacz NJ. 2012. Preliminary Findings of Research Investigating Habitat Use, Movement Patterns , and Population Structure of Bull Trout in the Prairie Creek Watershed. Fisheries and Oceans Canada.

SARA. 2016. Species Profile – Species at Risk Registry. Accessed April 2016. (www.registrelep-sararegistry.gc.ca/default_e.cfm).

4.0 MVEIRB IR # 28 – POTENTIAL EFFECT PATHWAYS

Request

Please describe all potential effects pathways of impacts of the road on fish health. Examples of pathways not currently considered include, but are not limited to, the effects of increased sedimentation on survival and emergence and development rates of fish larvae and eggs, gill damage, stress response, reduced resistance to disease and feeding rates, and the potential chronic and acute effects of spills on fish health. If these potential effects are excluded from assessment, please explain this exclusion.

Response:

If an aquatic impact is severe enough, most effects pathways can result in a reduction in fish populations, but the health of individual fish can be an important assessment endpoint for less severe effects. Aspects of fish health (including health indices) can also be used as early measurement indicators of an impact that may later result in a decreased population. Examples of potential road related impacts to fish health effects (and associated causes) are:

- Survival and emergence of fish larvae and eggs – physical smothering from the deposition of fine sediments on spawning gravels or exposure of developing eggs to metals, acid or hydrocabons from a spill.
- Gill damage – often erosion to gill lamellae from the exposure of fish to high TSS for extended periods. However, gill damage can also arise from exposure to caustic substances such as acids;
- Stress response – from blasting, or exposure to high TSS for extended periods;
- Reduced resistance to disease, including parasites – can be a result of prolonged physical stress, but can also be a result of insufficient food for energy needs;
- Increased susceptibility to predation – weak, unhealthy fish may not be able to escape predators;
- Decreased feeding rates – often impacts fish that are visual hunters due to an inability to see prey in water with high turbidity;
- Chronic effects related to accumulation of metals from environment (or spilled concentrate), or cumulative stress associated with multiple periods of high turbidity; and
- Acute effects related to the narcotic effect (polar narcosis) of hydrocarbon spills, significant changes in pH possibly associated with an acid spill and damage to a fishes swim bladder during blasting.

An updated list of potential effect pathways and associated residual effects analysis is provided below:

4.1 ENCROACHMENT ON SUNDOG CREEK

Effect Pathway -in a small number of locations the proposed road will encroach on Sundog Creek, causing loss of fish habitat (rearing habitat for Arctic grayling and sculpin) and possible spawning habitat for sculpin.

Residual Effects Analysis

Possible impact	Loss of fish habitat, possibly including rearing habitat (Arctic grayling and sculpin) and spawning habitat (sculpin). Ultimate impact on fish may be a reduction of fish population.
Significance (High/Moderate/Low) **&** **Rationale**	Low Re-alignment of the creek will result in no net loss of normally wet fish habitat.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Only associated with two locations on Sundog Creek; approximately 50 m long each.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation.
Magnitude (High/Moderate/Low)	Low (channel will be redirected into an existing, currently dry former channel, area affected is very small)
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low

4.2 SUNDOG CREEK RE-ALIGNMENT – TEMPORARY BENTHOS LOSS

Effect Pathway – re-alignment of sundog creek down a historical (currently dry) channel will result in temporary reduction in benthic invertebrate biomass as channel stabilizes. Lower quantities of fish food items may impact health of resident fish.

Residual Effects Analysis

Possible impact	Temporary loss of fish habitat as the new channel becomes stable. Lower quantities of fish food items (benthic invertebrates) from this area may result in a reduction of fish health and if severe, possible impact on fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Impact anticipated to have a low magnitude, high reversibility and small geographical range (relative to whole Sundog Creek). Furthermore, the habitat in the new channel will be comparable to what currently exists, therefore no net loss of habitat is anticipated. In addition, the original channel will mostly remain, but will be blind. Lower flows in this blind channel may provide refuge to fish during flood events.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Approximately 1.6 km
Timing (Duration, Frequency, and Extent)	1 to 3 years – construction of road only
Magnitude (High/Moderate/Low)	Low (channel will be redirected into an existing, currently dry channel, area affected is very small relative to the length of Sundog). In addition, this zone of Sundog naturally goes to ground in the summer and fall. Therefore, it is anticipated that the area has a lower natural productivity than areas immediately downstream that have flowing water much of the year.
Reversibility (High/Moderate/Low)	High – benthic invertebrate assemblages should stabilize within three years
Likelihood (High/Moderate/Low)	High

4.3 SUNDOG CREEK RE-ALIGNMENT – TSS AND FISH HEALTH

Effect Pathway – The Sundog diversion may result in a short period where fine materials from the new channel are suspended and result in downstream Sundog Creek water with a higher TSS. The greater TSS has the potential to result in impacts on resident fish health. However, as flows develop in spring, fines are likely to be washed into interstices between cobbles. Also, the duration and area of higher TSS is likely to be short and small, as well as upstream of grayling that may have overwintered in deep pools about 1 km downstream. However, some sculpin may be closer.

Residual Effects Analysis.

Possible impact	A possible elevation in downstream TSS on Sundog Creek could impact fish health, including damage to gills, stress, and reduced resistance to disease. Both Arctic grayling and slimy sculpin are visual hunters, therefore water having higher TSS can result in reduced feeding rates. If the effect occurs over a long period of time, it may decrease reproductive rates and increase mortality rates of fish.
Significance (High/Moderate/Low)	Low
& **Summary of Rationale**	Anticipated short duration and low magnitude of effect
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Impact would occur in Sundog Creek downstream of the new channel. Geographic range likely less than 100 m (note, a major tributary joins immediately downstream of the re-alignment).
Timing (Duration, Frequency, and Extent)	Likely an early spring short pulse of water with higher TSS
Magnitude (High/Moderate/Low)	Low - a substantial proportion of water flowing through this portion of Sundog flows subsurface and will not be influenced by fines exposed in the new channel. As water levels rise in spring, downstream TSS may rise as a result of flow going through the new channel. During a flood event, local mountain streams including Prairie and Sundog Creeks are known to be naturally turbid (Pers Com David Harpley). During flood flows, the incremental input of TSS from the new channel is anticipated to be negligible. Fish living in Sundog Creek likely have adapted to short periods of high TSS water, given that these occur naturally.
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	High

4.4 SUNDOG RE-ALIGNMENT – SPAWNING HABITAT.

Effect Pathway – The Sundog diversion may result in a short period where fine materials from the new channel are suspended and deposited in slower moving water downstream. The deposition of fine material has the potential to smother Arctic grayling spawning habitat, if present. However it is anticipated that the first flush will occur gradually and be diluted by sub-surface flow, as well as flow from a major tributary joining from the north and immediately downstream. Also, Sundog is known to be naturally turbid during freshet and spawning habitat exists in this system despite periods of high TSS. Therefore, the anticipated small incremental amount of fine suspended solids coming off the new channel at any given time should not significantly influence existing downstream grayling spawning habitat.

Residual Effects Analysis.

Possible impact	Deposited materials from the new channel could smother Arctic grayling spawning habitat, resulting in impacts on survival and emergence and development rates of fish larvae and eggs. The ultimate impact could be reductions in Arctic grayling populations
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Low magnitude of effect, small range and high reversibility
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Geographic range of an effect would be small, localized to slower moving water likely within a few hundred metres downstream of the diversion. Some fines may travel further downstream, but anticipated dilution will result in negligible incremental increases in TSS in water (and associated deposition in slower moving water) above background levels >1km downstream of the diversion.
Timing (Duration, Frequency, and Extent)	Early in first spring. Since the deposited material would be similar to material naturally in the creek, It is anticipated that spawning gravels would return to normal during the same freshet.
Magnitude (High/Moderate/Low)	Low - we anticipate that influence on overall spawning habitat in Sundog Creek to be very small.
Reversibility (High/Moderate/Low)	High – the material deposited represents natural Sundog Creek bed material. This is the same material that would be naturally mobilized throughout the creek during natural food events. It is anticipated that any deposits of fine sediments smothering spawning habitat would be washed out during higher flows.
Likelihood (High/Moderate/Low)	Moderate – unlikely that there is sufficient material to be mobilized and then deposited in a small area that is important spawning habitat

4.5 HABITAT FRAGMENTATION.

Effect Pathway – Culverts and or bridges are constructed in a way that may prevent or discourage fish from migrating to complete critical life stages.

Residual Effects Analysis

Possible impact	Fragmentation of fish habitat (i.e., barriers to fish movement). Results in possible impacts to fish populations. Many fish species found in the Nahanni watershed must migrate in order to complete their life cycle.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low We are confident that fish bearing streams have been identified and the selected crossing type will not impede fish passage. (Previously discussed in the DAR 11.6.1, p244, and Item 4.16 and 16.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Only associated with crossings, but can affect fish travelling long distances.
Timing (Duration, Frequency, and Extent)	20 years – life of mine + reclamation
Magnitude (High/Moderate/Low)	Low –clear span bridges at major crossings over fish bearing streams. For small creeks, installation of culverts will follow best management practices and will have natural substrate in bottom. Regular inspections to ensure they do not become blocked.
Reversibility (High/Moderate/Low)	High – if a culvert is impeding fish movement, it can be redesigned and replaced.
Likelihood (High/Moderate/Low)	Low

4.6 NOISE

Effect Pathway – Vibrations in aquatic habitat caused by passing vehicles on the all season road may illicit a startle reflex in nearby fish. Fish may not choose to use important habitat. If fish cannot move away from the noise, their health may be impacted as a result of stress.

Residual Effects Analysis

Possible Impact	All season road traffic noise may lead to stress and behavioral change in fish residing in aquatic habitat adjacent to the road. The ultimate impact may be reductions in fish populations in creeks that are either adjacent to or crossed by the all season road. Impact most likely if critical habitat occurs adjacent to the road.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Thresholds of noise under water adjacent to the road are unlikely to elicit a startle reflex in resident fish. It is anticipated that vibrations will be below the threshold expected to result in an effect (previously discussed in the DAR 11.4.2, p241, and item 8.4 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Seven spanned and approximately the same number of culvert crossings of fish bearing and potentially fish-bearing streams, and approximately 14.4 km of road that parallels and is within 30m of a fish bearing stream (Prairie 1.9, Fast 0.2, Funeral 4.8, Sundog 7.1, Polje 0.2, Grainger 0.2). The 30m is a conservative estimate, given that research indicates that there will be no impacts to fish.
Timing (Duration, Frequency, and Extent)	20 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Low (clear-span bridges will minimize noise at major crossings; fish will likely not perceive or acclimate to small incremental amount of noise adjacent to roads).
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low – based on existing literature and types of fish species (hearing generalists) living in habitat most likely to be influenced by noise.

4.7 SPILLED CONCENTRATE – CHRONIC FISH EXPOSURE

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact fish health and/or fish tissue concentrations. If the magnitude of the effect is large enough, a reduction in fish populations may be observed.

Residual Effects Analysis

Possible Impact	Spilled concentrate could impact fish health and or fish tissue concentrations of metals. Spill could result in chronic effect on fish health, possibly resulting in decreases in fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Risk of impacts are low due to very low likelihood of a spill, high likelihood of thorough clean-up if one occurred, and low leaching potential of concentrates.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.8 SPILLED CONCENTRATE – SPAWNING HABITAT

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact fish reproduction if concentrate precipitates in spawning habitat. The concentrate could result in physical smothering of developing eggs, or the metals in the concentrate could leach out and impact the development and emergence of larval fish. If the magnitude of the effect is large enough, a reduction in fish populations may be observed.

Residual Effects Analysis

Possible Impact	Fish eggs and developing embryos may be impacted if spilled concentrate settles out in spawning habitat. Developing fish may be affected either by physical smothering or by bioavailable metals leaching from concentrate in sediments – chronic effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Due to very low likelihood of a significant spill, high likelihood of thorough clean-up, and small predicted geographic range of effects if a spill occurred.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.9 SPILLED CONCENTRATE - BENTHOS

Effect Pathway – A spill of concentrate into one of the creeks adjacent to the road could impact benthic invertebrate habitat if concentrate precipitates out on to bottom substrates. The concentrate could physically smother productive benthic invertebrate habitat, or the metals in the concentrate could leach out and impact benthic invertebrate species assemblages. A significant decrease of benthic invertebrates downstream of a spill could impact fish health of fish dependent on benthic invertebrates as a major source of food.

Residual Effects Analysis

Possible Impact	Possible reduction of benthic invertebrate assemblages in streams downstream of a concentrate spill location. Most likely to impact depositional habitats. Ultimate effect would be a reduction of fish health and population due to reduction in available benthic invertebrates for food – chronic effect.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Low, due to a very low likelihood of a significant spill, high likelihood of thorough clean-up, and low leaching potential of metals in concentrate
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate to high – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush sediments. However, a spill to depositional habitat would take longer to recover.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.10 SPILLED FUEL OR OIL - BENTHIC INVERTEBRATES

Effect Pathway – A spill of fuel or oil into one of the creeks adjacent to the road could impact benthic invertebrate habitat if deposits coat substrates. Hydrocarbons have the potential to physically alter benthic invertebrate habitat, as well as being toxic. A significant reduction in the abundance of benthic invertebrate abundance downstream of a spill could impact fish health of fish dependent on benthic invertebrates as a major source of food.

Residual Effects Analysis

Possible Impact	Possible reduction of benthic invertebrate assemblages in streams downstream of a fuel or oil spill location. Ultimate effect would be a reduction of fish health and population due to reduction in available benthic invertebrates for food – chronic effect.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Low, due to a very low likelihood of a significant spill, high likelihood of thorough clean-up, moderate reversibility of material. Geographical range of effect likely small.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Likely small, downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences. Greater distance will result in greater dilution.
Timing (Duration, Frequency, and Extent)	17 years – life of mine.
Magnitude (High/Moderate/Low)	Low to moderate, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	Moderate – smaller volumes discharged to larger creeks will be more reversible. Fortunately fish are typically found in larger creeks. A complete season may be required to flush residues from rocks and sediments. A spill to depositional habitat would take longer to recover.
Likelihood (High/Moderate/Low)	Low - with effective mitigation measures, likelihood should be negligible.

4.11 SPILLED FUEL - FISH

Effect Pathway – A spill of fuel into one of the creeks adjacent to the road could acutely impact fish health. A significant release has the potential of killing fish downstream of a spill site.

Residual Effects Analysis

Possible Impact	Fish mortality and resulting reduction of fish population due to accidental spill of fuel to creeks- acute effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Probability of spill of a size that would result in a significant impact is low. Fuel would not reside in the environment for very long (previously discussed in DAR 9.4 & 9.5, p 191 – 200, and Item 6.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	Spill could occur anytime during mine operation, however impact of a single spill event should not be long lasting (acute).
Magnitude (High/Moderate/Low)	Low to high, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	High –fuel is not anticipated to reside in creeks for very long. Fuel will stay mostly on the surface of water and will evaporate.
Likelihood (High/Moderate/Low)	Low (with effective mitigation measures, likelihood should be negligible).

4.12 SPILLED ACID

Effect Pathway – A spill of acid into one of the creeks adjacent to the road could acutely impact fish health. A significant release has the potential of killing fish downstream of a spill site.

Residual Effects Analysis

Possible Impact	Fish mortality and resulting reduction of fish population due to accidental spill of acid to creeks- acute effect
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Probability of spill of a size that would result in a significant impact is low. Acid would not reside in the environment for very long (previously discussed in DAR 9.4 & 9.5, p 191 – 200, and Item 6.3 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Downstream of spill location; distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	Spill could occur anytime during mine operation, however impact of a single spill event should not be long lasting (acute).
Magnitude (High/Moderate/Low)	Low to high, depending on the amount of material spilled and size of stream affected.
Reversibility (High/Moderate/Low)	High –acid is not anticipated to reside in creeks for very long. Acid is highly soluble in water and will rapidly dilute.
Likelihood (High/Moderate/Low)	Low (with effective mitigation measures, likelihood should be negligible).

4.13 SURFACE EROSION – SPAWNING HABITAT SMOTHERING

Effect Pathway – Road-related surface erosion and associated sedimentation in adjacent creeks may lead to smothering of spawning habitat.

Residual Effects Analysis

Possible Impact	Smothering of spawning habitat can result in impacts on developing fish embryos and the loss of important spawning habitat can result in impacts on fish populations. If smothering occurs while fish eggs are within substrates, developing fish will die due to a lack of oxygen.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Sedimentation of materials eroded from the all season road or its embankments is not anticipated. Times of greatest potential will coincide with periods of high natural TSS in local streams and incremental amount of TSS is anticipated to be negligible. Best management practices of road building will be followed which will mitigate the potential for significant erosion. Adaptive management approaches will mitigate significant erosion if observed. As evidence, there have been no apparent negative effects from the existing road along Prairie and Funeral Creeks.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In- frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will mitigate possible impact).
Reversibility (High/Moderate/Low)	High – one season may be required to flush sediments. Fish should quickly recolonize impacted sections.
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.14 SURFACE EROSION – BENTHOS SMOTHERING

Effect Pathway – Road-related surface erosion and associated sedimentation in adjacent creeks may lead to smothering of benthic invertebrate habitat.

Residual Effects Analysis

Possible Impact	Smothering of benthic invertebrate habitat could result in a decrease in benthic invertebrate populations, possibly reducing the quantity of fish food available in the creek. Insufficient food can impact fish health and ultimately fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Sedimentation of materials of eroded from the all season road or its embankments is not anticipated. Times of greatest potential will coincide with periods of high natural TSS in local streams and incremental amount of TSS is anticipated to be negligible. Best management practices of road building will be followed which will mitigate the potential for significant erosion. Adaptive management approaches will mitigate significant erosion if observed.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Distance dependent on flow velocity, time and dilution from downstream confluences.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In- frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will minimize possible impact).
Reversibility (High/Moderate/Low)	High – one season may be required to flush sediments. Fish should quickly recolonize impacted sections. Bull trout returning to Funeral Creek may take longer to recolonize (therefore “moderate”).
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.15 SURFACE EROSION - TSS

Effect Pathway – Road-related surface erosion and associated increases in total suspended sediments in water creeks may lead to impacts on fish health.

Residual Effects Analysis

Possible Impact	Road-related surface erosion may result creek water with a higher TSS downstream. Water with a high TSS has been linked to impacts on fish, including damage to gills, increased stress response, greater resistance to disease and difficulty locating food items.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Anticipated to result in a short-term (acute) exposure and can be corrected using adaptive management.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Can influence all water downstream of the surface erosion.
Timing (Duration, Frequency, and Extent)	25 years – construction of road, operation and reclamation. In-frequent, if occurs, despite mitigation measures, would be associated with heavy precipitation.
Magnitude (High/Moderate/Low)	Low (sediment and erosion control plan will minimize possible impact).
Reversibility (High/Moderate/Low)	High – with the cessation of heavy rainfall, surface erosion should stop. CZN will take corrective action where erosion is causing noticeable turbidity increases downstream of the all season road.
Likelihood (High/Moderate/Low)	Low for significant events that might result in an effect.

4.16 REMOVAL OF RIPARIAN VEGETATION – FISH FOOD

Effect Pathway – Removal of riparian vegetation may reduce availability of fish food items (largely terrestrial insects), and consequently impact fish populations.

Residual Effects Analysis

Possible Impact	Riparian vegetation is important habitat for terrestrial invertebrates that often become fish food items. Riparian vegetation also provides organic carbon to streams that many benthic invertebrates will consume. The potential loss of invertebrate food items associated with either of these mechanisms can result in a decrease in food available to fish. A decrease in available food has the potential to impact fish health and possibly fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low The loss of fish food items is anticipated to be negligible (previously discussed in Item 16.4, response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	In most cases, the road will be crossing creeks and therefore the amount of riparian vegetation removed relative to what is available will be minimal. In some cases, the road will parallel creeks and be within 30 m. In the majority of these cases, the existing riparian vegetation is minimal.
Timing (Duration, Frequency, and Extent)	35 years – construction of road, operation and reclamation. Plus time for succession.
Magnitude (High/Moderate/Low)	Low – the removal of vegetation will generally remove a small portion of existing riparian vegetation.
Reversibility (High/Moderate/Low)	Moderate (once road is decommissioned, riparian vegetation will be returned to its natural state). Due to harsh climatic conditions and short growing season, plant growth is slow, therefore it may take several decades for the road surface to return to a vegetated state.
Likelihood (High/Moderate/Low)	Low for significant effects to fish populations.

4.17 REMOVAL OF RIPARIAN VEGETATION - COVER

Effect Pathway – Removal of riparian vegetation may reduce available stream cover. Resulting poorer fish habitat can influence fish behavior and fish health.

Residual Effects Analysis

Possible Impact	Removal of riparian vegetation may result in a reduction of stream cover. Stream serves to protect fish from predation and also acts to regulate diurnal changes in stream temperature. A reduction in cover may result in greater stress to fish and impact fish behavior, fish health and possibly influence fish populations.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low Most streams along the all season road appear to provide little cover to adjacent streams. Only the smallest streams having little flow tend to have riparian growth providing good cover.
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Very small –riparian cover was only observed on very small streams and only where there is a perpendicular crossing, so vegetation removal will be minimal. Also most of these smaller creeks are unlikely to be fish bearing.
Timing (Duration, Frequency, and Extent)	35 years – construction of road, operation and reclamation. Plus time for succession.
Magnitude (High/Moderate/Low)	Low – the removal of vegetation will generally remove a small portion of existing riparian vegetation.
Reversibility (High/Moderate/Low)	Moderate (once road is decommissioned, riparian vegetation will be returned to its natural state). Due to harsh climatic conditions and short growing season, plant growth is slow, therefore it may take several decades for the road surface to return to a vegetated state.
Likelihood (High/Moderate/Low)	Low for significant effects to fish populations.

4.18 BLASTING

Effect Pathway – Blasting adjacent to water bodies has the potential to startle fish if not result in severe health impacts, resulting in death. At its worst, blasting could result in impacts on fish populations.

Residual Effects Analysis

Possible Impact	Percussion waves can damage swim bladders of fish, injuring or killing fish. If significant, fish populations may be impacted.
Significance (High/Moderate/Low)	Low
& **Summary of Rationale**	Application of DFO guidance will avoid impact to fish (previously discussed in Item 16.4, response to adequacy review).
Uncertainty (High/Moderate/Low)	Low
Geographic Range (Area or Distance)	Blasting at only two locations where fish are known to exist. No species of special concern at either location.
Timing (Duration, Frequency, and Extent)	Maximum one week per location during construction.
Magnitude (High/Moderate/Low)	Low – because the DFO guidance will be applied. Also most locations will not be fish habitat at the time of blasting. Fish will be encouraged to leave immediate area before and during blasting. Other mitigation procedures as provided in blasting management plan. No species of concern resident at site.
Reversibility (High/Moderate/Low)	High – fish will return to site after blasting has been completed.
Likelihood (High/Moderate/Low)	Low

4.19 OVERHARVESTING

Effect Pathway – Creation of an all season road will provide new access to fisherman. Over-harvesting can result in impacts on fish populations.

Residual Effects Analysis

Possible Impact	Increased access to fishing along the all-season road could affect stocks of traditionally harvested fish species. Most creeks in Nahanni are nutrient poor and therefore fish abundances tend already to be low.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low The low abundance of fish along the all season road, combined with the check-point planned should reduce fishing pressures. In addition, authorized users on CZN business will be prohibited from fishing along the road (previously discussed in DAR 4.5.2, p 100, and Item 6.3, 15.2 in response to adequacy review).
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Sections of several larger creeks and two lakes.
Timing (Duration, Frequency, and Extent)	23 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Likely low due to low desirability of fish along the road.
Reversibility (High/Moderate/Low)	High
Likelihood (High/Moderate/Low)	Low for significant overharvesting (knowing that fish stocks are not highly desirable, controls on use of road will minimize access by fishermen).

4.20 STRANDING

Effect Pathway – the diversion and road encroachment of Sundog Creek may result in the increased potential for fish to be stranded in shallow depressions as flows decrease and water goes to ground after freshet.

Residual Effects Analysis

Possible Impact	The stretch of Sundog Creek where the diversion is planned goes dry in summer and remains dry until freshet unless there is a heavy rainfall even in summer. Currently there is some concern that fish may become stranded as the water in the creek goes to ground. One concern with the diversion of Sundog Creek near km36 is that it has the potential of causing a higher incidence of fish stranding if pools or shallow indentations are created that did not formerly exist. This could also apply at km38, where the road will encroach on the creek Changes in creek hydrology may increase the period of time each year when stranding is possible.
Significance (High/Moderate/Low) **&** **Summary of Rationale**	Low The habitat created by diverting the thalweg into a pre-existing secondary channel will be very similar to the existing channel and therefore no increased incidence of stranding is anticipated. The Mine will also monitor the portion of the existing channel remaining to ensure that fish are not being stranded as flows recede in early summer. Creek profile will be maintained in other encroachment areas.
Uncertainty (High/Moderate/Low)	Moderate
Geographic Range (Area or Distance)	Small areas along the 1.6km route of the new proposed channel, as well as inside the existing channel (1.4km) which will become a blind channel once the main flow is diverted.
Timing (Duration, Frequency, and Extent)	23 years – life of mine + reclamation.
Magnitude (High/Moderate/Low)	Likely low – it is anticipated that few if any fish would stay in shallow pools and become stranded
Reversibility (High/Moderate/Low)	High – stranded fish can be netted and relocated downstream. Any pools capable of causing stranding can be filled in.
Likelihood (High/Moderate/Low)	Low – this is something that can be monitored and corrected if found to be a problem

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