Information Request 17

Responses to Information Request 17

IR 17 – Pit Lake and Fish Habitat

References:

EIS Guidelines, Section 2.7.2.4.2
EIS, Section 2.7.2.4
EIS Appendix 2.7.2.1-I (Water Quality Prediction Results)

Related Comments:

CEAR # 277 (Fisheries and Ocean Canada)
CEAR # 290 (Tsilhqot'in National Government)

Rationale:

In conducting the effects assessment for water quality and aquatic ecology, the EIS Guidelines state that the EIS shall include an evaluation of water quality in Pit Lake including consideration of the effects of pit depth in relation to mixing and anoxic conditions, release of metals from pit walls, and acid production, and to include an assessment of the degree of uncertainty associated with these predictions.

The EIS states that upon cessation of mining activities, the open pit will fill to its designed spill elevation over a period of approximately 28 years, releasing water into lower Fish Creek in year 48 (p. 138). The Proponent notes (p. 1465) that "there will be no capability for fishing in the Pit Lake predicted at this time" (*i.e.* post-closure).

Information Requested:

The Panel requests that the Taseko:

a. Provide an assessment of the suitability of Pit Lake for fish at post-closure including consideration of the effects of Pit Lake depth in relation to mixing and anoxic conditions and an assessment of the degree of uncertainty associated with these predictions.

b. Describe the ability for fish to access Fish Lake and the anticipated timelines for the use of Pit Lake as fish habitat, if appropriate.

Information Request #17a

Provide an assessment of the suitability of Pit Lake for fish at post-closure including consideration of the effects of Pit Lake depth in relation to mixing and anoxic conditions and an assessment of the degree of uncertainty associated with these predictions.

Response Summary

The use of Pit Lake as fish habitat is technically and biologically feasible. Based on relative depth (relation of surface area to depth), there is a high probability that Pit Lake would become stratified during the infilling process and that mixing/turnover would not occur at depth. As such, oxygen depletion layers, dissolved metals and other contaminants would remain at depth and not mix vertically throughout the water column. The following provides examples and methods for the improvement of specific water quality parameters (if/as required for Pit Lake) and for the creation/enhancement of productive littoral fish habitat for abandoned mine pits throughout Canada.

Discussion

The following discussion briefly describes relevant information found in a Canadian Technical Report of Fisheries and Aquatic Sciences 2826 – *Creating lakes from open pit mines: processes and considerations, with emphasis on northern environments*. (Gammons et al. 2009)

Lakes with high depth to width ratios have a low likelihood of turnover (i.e., vertical mixing of layers of varying density) and are often permanently stratified (meromictic lakes; Doyle and Runnells 1997, Castro and Moore 2000). Pit lakes from mining operations are typically meromictic and contain a deep layer of saline water (monimolimnion) with a higher density that does not mix with the upper levels (mixolimnion; Boehrer and Schultze 2006, Gammons et al. 2009). Anoxic conditions in the monimolimnion are common, due to respiration of organic material, limited photosynthetic activity, lack of gas exchange with the atmosphere, and chemical processes (Boehrer and Schultze 2006). See Appendix A for a list of meromictic pit lakes.

Calculation of a lake's aspect ratio or 'relative depth' (Hutchinson 1957) can be used to determine whether or not lake turnover will occur:

$$Z_r\,(\%) = 50 \cdot Z_m \cdot \frac{\sqrt{\pi}}{\sqrt{A}}$$

where Zm is the maximum depth, and A is the surface area of the lake. In a survey of mining pit lakes around the world, Doyle and Runnells (1997) determined that most having an aspect ratio of greater than 25% are meromictic.

Using the characteristics of the New Prosperity Pit Lake as described in the EIS (max depth = 525 m, and surface area = 166 ha), the predicted relative depth of Pit Lake is 36.1%, indicating there would be a high probability it would be permanently stratified. However, there are various additional factors that influence the likelihood of mixing in pit lakes. There is a more useful equation for predicting lake turnover (Gammons et al. 2009) that incorporates some of these additional determining factors, but the values for some essential variables of that equation, such as depth of surface layer in lake, are unknown at this time.

The capability of Pit Lake to support fish ultimately depends on water quality as well as suitable habitat characteristics for fish of all life stages. Some common water quality characteristics of pit lakes include low pH levels, elevated levels of ‘cationic’ trace metals (i.e. Cu^{2+}, Fe^{2+}/Fe^{3+}, Al^{3+}) and common cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), high total dissolved solids (TDS), high turbidity (TSS), oxygen depletion in deep zones, and low nutrient levels. As such, information regarding the underlying geology and metals relative abundance and distribution would be required at depth to determine various site-specific factors that can influence water quality. Several strategies can be implemented to enhance the end water quality of a pit lake (Table 17A-1).

Table 17A-1. Strategies for enhancing end uses of pit lakes. This table was adapted from Section 4.2 of Gammons et al. (2009, and references therein).

Strategy	Purpose of Strategy	Implementation	Main Disadvantage
Rapid Flooding	Neutralization potential of rock walls decreases with time due to natural weathering and can increase risk of acid mine drainage. Filling lakes rapidly decreases this risk.	Fill lake over a relatively short period of time	Uncertainty of final Pit Lake water quality
Chemical Treatment	Adjust pH to a level suitable for aquatic life.	Addition of alkaline reagents, such as lime or sodium hydroxide	Solid precipitate ('sludge') created by lime treatment can increase turbidity of surface waters.
Biological Treatment (Use algae and/or bacteria to improve water quality)	Precipitates from aerobic bacterial reactions adsorb trace metals from lake water.	Add organic compounds (livestock waste, straw, sediment from nearby lakes etc.) to speed up natural rate of biological activity	Can lower pH of lake
	Algae can raise pH of surface waters via CO_2 consumption, sorb metals from solution and/or use metals in metabolic activities, as well as provide food for higher organisms.	See above	
	Anaerobic bacteria in deep portions of lake conduct bacterial sulfate reduction (BSR), which raises pH, decreases sulfate levels and promotes metal precipitation as insoluble sulfide minerals.	See above	If lake turnover occurs, then organisms may be exposed to H_2S.

High quality fish habitat within a lentic waterbody requires littoral habitat (< 6 m depth) with structural diversity and complexity that provide adequate area for forage, refuge, as well as rearing, spawning (for lake spawning individuals) and overwintering habitat. Mining pit lakes inherently lack low-grade slopes and shoals that provide shallow littoral habitat within the euphotic zone capable of primary and secondary production (i.e., phytoplankton, zooplankton, alga and benthic organisms), required by fish. As such, mining pit reclamation plans need to consider the creation of shoal-type habitat with the addition of diversity and complex habitat features. Gammons et al. (2009) provides several examples of fish habitat enhancement strategies used in the reclamation of mining pit lakes in Canada (Table 17A-2; Figure 17A-1).

Table 17A-2. Potential methods of fish habitat enhancement in Pit Lake (Gammons et al. 2009 and references therein).

Habitat Component	Restoration and/or Enhancement Technique	Fish-Specific Function	Additional Function
Riparian Zone	Landscape perimeter of pit lake such that riparian zone is able to support vegetation. Plant native vegetation or allow it to establish naturally in riparian zone.	Autochthonous inputs from riparian vegetation provides a food source for fish and their prey.	Acts as buffer from surrounding land uses, stabilizes shorelines, dead components of riparian vegetation act as a food source for microorganisms and provide nutrient input for littoral vegetation.
Littoral Zone	Littoral habitat may be created by: "…bulldozing, drilling or blasting upper walls onto the upper bench of the pit, partial backfilling with mine waste, manual construction of bays around periphery of pit."	Fish may utilize the littoral zone (and it's inherent habitat components) as spawning, rearing and feeding habitat, and for refuge sites.	Shallow water habitat in the littoral zone allows for growth of aquatic vegetation, and establishment of littoral benthos.
Woody Debris	Place logs, woody brush piles, log piles or bundles of native conifers at varying depths throughout littoral areas of the lake.	Provides cover for juvenile fish and has been shown to increase fish abundance	These structures create habitat for invertebrates and microorganisms.
Artificial Reefs	Create 'reef' habitat by piling waste or excavated rock in the littoral zone.	Artificial reefs provide interstitial refuge sites for juvenile fish.	These structures create habitat for invertebrates and microorganisms
Floating Reef-Raft	Create a wooden 'raft' covered with various organic materials (soil, grass, coarse woody debris) and anchor this raft to the lake bottom in the littoral zone.	While artificial reefs are more desirable than floating reef-rafts, the latter also provides cover for fish.	These structures create habitat for invertebrates and microorganisms.

Habitat Component	Restoration and/or Enhancement Technique	Fish-Specific Function	Additional Function
Floating Islands	Floating islands consist of a platform that supports wetland plants, and they act similarly to wetland islands. These can be purchased from such companies as Floating Islands International (http://www.floatingislandinternational.com).	Cover habitat for fish and their food sources.	Similarly to floating reefs, these 'islands' provide habitat for invertebrates and microorganisms as well as for waterfowl and aquatic mammals.
Littoral Macrophytes	Plant or seed a variety of native aquatic plants including both emergent and submergent vegetation and shoreline vegetation (sedges, rushes etc.)	Cover for juvenile fish and ambush cover for piscivorous fish.	Aquatic vegetation can increase dissolved oxygen levels, provide substrate for algae and habitat for invertebrates, aid in nutrient cycling and help stabilize shorelines.

Figure 17A-1. Schematic of fish habitat creation and enhancement taken from (Gammons et al. 2009).

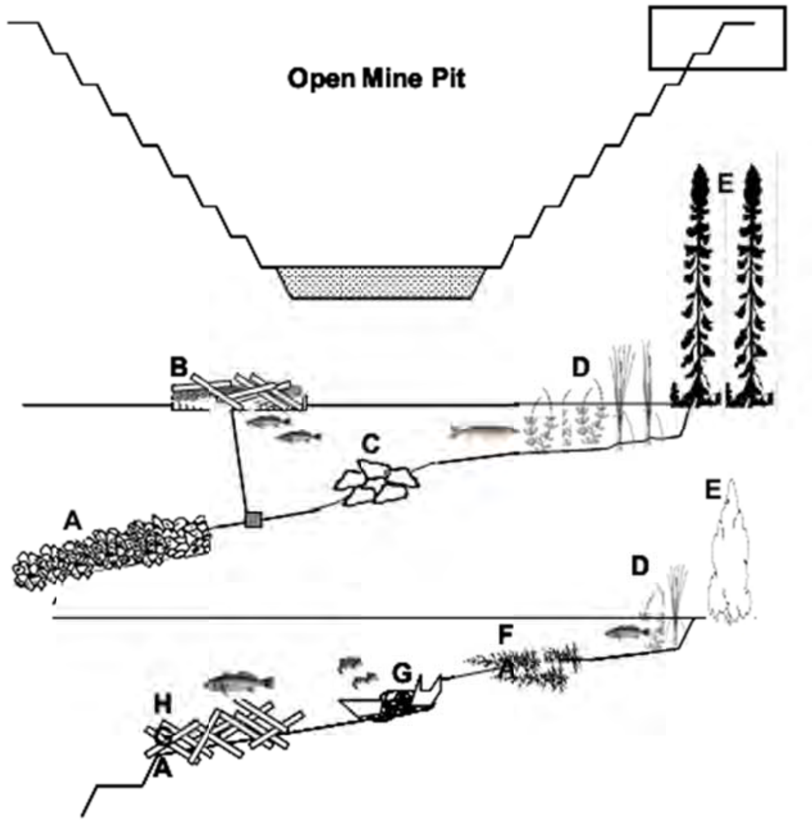

Figure 23. Examples of fish habitat creation and enhancement techniques as described in Section 4.2.5.2. Artificial reef created with rubble and waste-rock (A), floating reef-raft (B), large boulders for cover (C), the planting of littoral (D) and riparian vegetation (E), submerged conifers for providing cover (F), construction material such as donated concrete (G) and the addition of large woody debris (H).

Conclusion

The use of Pit Lake as fish habitat is technically and biologically possible. If the lake does not naturally become suitable for fish, there are numerous techniques available to adjust water quality and to create fish habitat.

Appendix A. Meromixis reported in pit lakes (table from Boehrer and Schultze (2006))

Lake (country) - mined material	Morpho-metric data*	Reasons for meromixis**	References
Berkeley Pit (USA) - copper	A: - V: >110† z_{max}: 220†	- formation of a less mineralised mixolimnion by - inflow of less mineralised water at the lake surface† - enrichment of iron and sulfate due to	Davis and Ashenberg 1989 Robins et al. 1997 Doyle and Runnells
1997			
		precipitation /sedimentation of secondary iron minerals in the mixolimnion, their re-dissolution in the monimolimnion and ongoing pyrite oxidation at the pit walls in the monimolimnion by ferric iron†	Jonas 2000 Gammons et al. 2003 Madison et al 2003 Pellicori et al. 2005
Island Copper Mine (Canada) - copper	A: 1.72 V: 241 z_{max}: >400	- first filling step with sea water (93% of volume) and second filling step with fresh water (7% of volume)	Fisher et al. 2000 Muggli et al. 2000 Fisher 2002 Poling et al. 2003 Stevens et al. 2005 Boehrer and Stevens 2005
Spenceville Copper Pit (USA) - copper	A: 0.002 V: 0.023 z_{max}: 17	- enrichment of substances due to evaporation - accumulation of iron and other substances in the monimolimnion due to microbial decay of organic compounds	Levy et al. 1997
Rävlidmyran Pit (Sweden) - zinc, copper, lead, silver, gold	A: 0.049 V: 0.53 z_{max}: 28.9	- primary filling with highly mineralised water caused by elution of pit walls and inflow of water of high TDS concentration due to pyrite oxidation†† - accumulation of iron and other substances in the monimolimnion††	Lu et al. 2003 Lu 2004

Anchor Hill Pit (USA) - gold, silver, copper, lead, zinc	A: 0.018 V: 0.26 z_{max}: 26	- measures to neutralize the lake (liming, addition of organic material to stimulate reductive microbial processes for alkalinity production	Lewis et al. 2003
McLaughlin Gold Mine, soth pit lake (USA) - gold	A: - V: - z_{max}: 85.3	- intrusion of saline water by subrosion of salt strata in the deeper underground - accumulation of CO_2 in the monimolimnion caused by thermal springs at the lake bottom	Rytuba et al. 2000
Brenda Pit (Canada) - molybdenum	A: 0.38 V: 20.7 z_{max}: >140	- no clear information given in the references	Stevens and Lawrence 1997 Hamblin et al. 1997 Stevens and Lawrence 1998 Hamblin et al. 1999
Gunnar (Canada) 1997	A: 0.07 V: - z_{max}: 110	- no clear information given in the reference	Doyle and Runnells
pit lake in southeast Tennessee[†††] (USA)	A: 0.08 V: 2.1 z_{max}: 60	- dilution of the mixolimnion by through flow of a stream[††] - primary filling with highly mineralised water caused by elution of pit walls and inflow of water of high TDS concentration due to pyrite oxidation[††]	Colarusso et al. 2003
St Louis (France) - coal	A: - V: - z_{max}: 60	- elution of pit walls and inflow of ground water of high TDS concentration due to pyrite oxidation[††]	Denimal et al. 2005
Fouthiaux (France) - coal	A: - V: - z_{max}: 37	- elution of pit walls and inflow of ground water of high TDS concentration due to pyrite oxidation[††]	Denimal et al. 2005

Mining Lake 111 (Germany) - lignite	A: 0.1 V: 0.5 z_{max}: 10.2	- inflow of ground water of high TDS concentration due to pyrite oxidation	Karakas et al. 2003
Goitsche (Germany) - lignite	A: 13.3 V: 213 z_{max}: 47	- inflow of ground water of high TDS concentration due to pyrite oxidation	Boehrer et al. 2003
Waldsee (Germany) - lignite	A: 0.003 V: - z_{max}: 5	- inflow of ground water of high TDS concentration due to pyrite oxidation - accumulation of iron and DIC in the monimolimnion	Rücker et al. 1999 Schimmele 1999
Lugteich (Germany) - lignite	A: 1.7 V: 3.5 z_{max}: 10	- inflow of ground water of high TDS concentration due to pyrite oxidation - accumulation of iron and DIC in the monimolimnion	Rücker et al. 1999
Moritzteich (Germany) - lignite	A: 0.16 V: 1.2 z_{max}: 17.5	- inflow of ground water of high TDS concentration due to pyrite oxidation - accumulation of iron and DIC in the monimolimnion	Stellmacher 2004
Hufeisensee (Germany) - lignite	A: 0.7 V: 6.1 z_{max}: 29	- intrusion of saline water by subrosion of salt strata in the deeper underground	Schreck 1998 Maiss et al. 1998 Stottmeister et al. 1999
Merseburg-Ost 1a (Germany) - lignite	A: 2.8 V: 30 z_{max}: 27	- intrusion of saline water by subrosion of salt strata in the deeper underground	Böhrer et al. 1998 von Roden and Ilmberger 2001 Boehrer et al. 2006
Merseburg-Ost 1b (Germany) - lignite	A: 2.3 V: 47 z_{max}: 36	- intrusion of saline water by subrosion of salt strata in the deeper underground	Böhrer et al. 1998 von Roden and Ilmberger 2001 Boehrer et al. 2006

* A – surface area in 10^6 m^2, V – volume in 10^6 m^3, z_{max} - maximal depth in m
** TDS – total dissolved solids, DIC – dissolved inorganic carbon
† presented information taken only from Pellicori et al. 2005
†† interpretation of the information in the references by Boehrer and Schultze
††† name of the lake is not given in the reference

Information Request #17b

Describe the ability for fish to access Fish Lake and the anticipated timelines for the use of Pit Lake as fish habitat if appropriate.

Taseko assumes that the question contains a typo and should be worded: Describe the ability for fish to access Pit Lake and the anticipated timelines for the use of Pit Lake as fish habitat if appropriate.

Response Summary

The ability for fish to migrate north of Fish Lake will be cut off one year before the mill start up. According to the water management modelling and the water balance, Pit Lake has filled and begins to discharge to Lower Fish Creek forty-nine years later during the Post Closure Phase. As soon as Pit Lake is suitable as fish habitat past this point in time, the fish barrier will be removed and fish will have access to Pit Lake and to Lower Fish Creek.

Discussion

For the purpose of the water quality modelling presented in the EIS, the water management plan has been broken down into six different time periods. These periods are:

a) Construction Phase…. The two years before mill start up

b) Operations Phase I…. Years 1 to 16. Mining and Milling operations are occurring

c) Operations Phase II…. Years 17 to 20. Milling operations are occurring. Mining has finished.

d) Closure Phase I…. Years 21 to 30. Operations finished. Water in the TSF directed to open pit

e) Closure Phase II…. Years 31 to 47. Water in TSF is directed to Fish Lake

f) Post Closure…. Year 48 onwards. Open pit has filled with water and begins to discharge to Lower Fish Creek

Construction Phase: The tailings storage facility (TSF) will begin storing water one year before mill start up. At the same time, Fish Lake outflow will begin to be recirculated to the upper reaches of the Fish Lake inlets. The ability for fish to access streams north of the Fish Lake outlet flood control dam will be removed at this time.

Operations Phase I: Fish Lake outflow continues to be recirculated to the Fish Lake inlets with excess water being pumped to and stored in the TSF. Fish will not have access north of the Fish Lake outlet flood control dam.

Operations Phase II: Fish Lake outflow continues to be recirculated to the Fish Lake inlets. Excess water not required for recirculation will be directed to the open pit. Although some water from Fish Lake will flow into the open pit, a fish barrier will be erected so that fish cannot access the open pit as it fills with water. Excess water in the TSF will also report to the open pit. Access for fish to Pit Lake will remain closed because the water quality in Pit Lake will be changing rapidly during this period.

Closure Phase I: Same as Operations Phase II.

Closure Phase II: Excess water from Fish Lake not required for recirculation will be directed to the open pit. Although water from Fish Lake will flow into the open pit, a fish barrier will bar fish from accessing the open pit as it fills with water. The TSF overflow is now routed to the Fish Lake inlets.

Post Closure Phase: Water has completely filled the open pit and is now discharging to Lower Fish Creek. The TSF overflow is routed to the Fish Lake inlets. Some, or all of the Fish Lake outflow will be directed to Pit Lake. The fish barrier between Fish Lake and the open pit will remain in place until the water in the open pit is of a quality that will support fish habitat.

The exact timing of when fish will be allowed access to Pit Lake has not been determined. Although Pit Lake has been modelled to be full approximately 49 years after flow is initially cut off north of Fish Lake, there are a number of factors that could change the time when the fish barrier between Fish Lake and Pit Lake would be removed. These factors include:

a) The amount of water that will be required for recirculation during Operations Phase II through to Closure Phase II will impact the amount of water from Fish Lake reporting to Pit Lake and therefore affecting the amount of time required to fill Pit Lake.

b) The timing of the start of Closure Phase II. Once the TSF water quality is acceptable for discharge to Fish Lake, this phase will begin. This could start earlier or later than the modelled 31st year and will affect the amount of time it would take to fill Pit Lake.

c) The length of time it takes to fill Pit Lake will have an effect on the Pit Lake water quality.

d) The proportion of water from Fish Lake and The TSF reporting to the Pit Lake will affect water quality in Pit Lake.

e) Once Pit Lake is full and its water quality monitored, a decision will be made as to whether it is ready for fish, whether to wait for natural processes to change Pit Lake into fish habitat, or whether mitigation will be implemented to speed up the process of changing Pit Lake into fish habitat.

Conclusion

While it is anticipated that fish will freely have access between Fish Lake and Pit Lake, the exact timing of this starting cannot be exactly determined. Water modelling currently predicts that the earliest that fish would have access to Pit Lake would be forty nine years after mill start up.