Information Request 25

Responses to Information Request 25

IR 25 – Lake Productivity- Mitigation Measures

References:

EIS, Section 2.6.1.5
EIS Appendix 2.7.2.4-B-A (Effects of Reduced Inflow on Fish Lake Trophic Status Using the Mass Balance Approach)
EIS Appendix 2.7.2.5-A (Fish and Fish Habitat Compensation Plan)
EIS Appendix 2.7.2.5-B (MMER Schedule 2 Compensation Plan)

Related Comments:

CEAR # 277 (Fisheries and Oceans Canada)
CEAR # 302 (Canadian Science Advisory Secretariat)
CEAR # 290 (Tsilhqot'in National Government)

Rationale:

In the EIS (Appendix 2.7.2.4B-A, p. 19), the Proponent states that: "In general, the trophic status of Fish Lake will remain largely unchanged with the reduced flow and re-circulated flow, at least in the short term, from the current meso-trophic status".

Model analyses for the construction and operational phases of the Project, and the accompanying flow and loading regimes, show that the trophic status of Fish Lake could change from the current baseline meso-eutrophic condition to a more productive, eutrophic state during the life of mine and beyond.

The EIS further indicates that mitigation measures will be implemented for the protection of water quality to buffer any increases in lake phosphorus concentrations and impacts on Fish Lake productivity if considered necessary.

The Proponent refers to phosphorus levels that, once exceeded, would trigger active mitigation. Based upon a reported range in baseline P conditions (15-42 µg/L P), the Proponent has determined critical concentrations requiring mitigation to be 22-63 µg/L. The reported trigger level, however, is broad, and transcends multiple trophic state classifications as presented in the EIS (Appendix 2.7.2.5-B, p. 45). It is unclear what critical P concentration would precipitate mitigation actions, particularly as baseline conditions overlap with the predicted threshold range.

Given the Proponent's conclusion that a more productive Fish Lake will result in algal proliferation with potential negative implications for overall water quality and lake biodiversity, more detail on the evaluation of trophic status and the threshold for initiating mitigation efforts is needed to accurately evaluate the efficacy of the proposed approaches to protect Fish Lake and the effects of eutrophication.

Information Requested:

The Panel requests that Taseko:

a. Clarify what critical P concentration would precipitate mitigation actions, particularly as baseline conditions overlap with the predicted threshold range.

b. Clarify what fraction of P is being used in the analysis or if total phosphorus (TP) is the metric being considered.

c. Discuss the likelihood of Fish Lake experiencing acute seasonal N-limitation in the surface water and the decisions to monitor and implement mitigation measures.

d. Provide information regarding what other important lake water quality variables will be monitored to assess the need for mitigation against eutrophication (e.g. measures of nutrient limitation such as TN:TP, POC:PON).

e. Provide an assessment of potential impacts of changes in ecosystem productivity that could occur in conjunction with changes in hydrology, physio-chemical inputs (such as turbidity, nutrients, temperature, chlorophyll), as well as the synergistic impact of the dissolved metals likely to enter the system.

f. Provide a discussion on the potential effects of aeration as a mitigation measure on the lake system as well as the effectiveness of the mitigation measures proposed in the EIS, including any documented success of this mitigation measure.

g. Provide a clarification on the length of time that re-circulation of flows to Fish Lake would be required.

h. Provide a discussion of the temporal and spatial scale for monitoring and maintenance of flow augmentation in order to maintain spawning habitat in the tributaries and maintain Fish Lake water balance and trophic status.

The Panel also requests that Taseko:

i. Provide details of the adaptive management goal for Fish Lake along with adaptive management options available that would ensure Fish Lake and its tributaries remain a biologically functioning ecosystem. Taseko is requested to consider Fish Lake at the ecosystem level and not simply provide the details for each VEC separately. Specifically, discuss which elements of the Fish Lake ecosystem would be monitored and potentially require mitigation in the long-term.

j. Describe the thresholds that have been established for adaptive management of Fish Lake and provide a rationale on how these thresholds were determined.

Information Request #25a

Clarify what critical P concentration would precipitate mitigation actions, particularly as baseline conditions overlap with the predicted threshold range.

Response Summary

Critical phosphorous concentration levels have not been determined at this point in the environmental assessment process. The Canadian Guidance Framework for the Management of Freshwater Systems published by the Canadian Council of Ministers of the Environment, 2004 for Phosphorus will form a basis for determining trigger, alert and action levels during permitting.

Discussion

Total Phosphorus (TP) concentrations in Fish Lake naturally fluctuate with the seasons. Measurements of Total Phosphorus (TP) levels in Fish Lake from 1993 to 2011 resulted in a range of values between 15 to 42 µg/L (see table 1 in Appendix 2.7.2.4B-A). Based upon these measurements, it has been assumed in the EIS that the seasonal TP reference levels range between 15 µg/L in autumn to 42 µg/L in the warmer summer growing season. Since the reference levels fluctuate with time of year, the trigger and alert levels would also fluctuate throughout the year to mimic the same changes in baseline TP concentrations. The trigger or alert concentration range of 22 to 63 µg/L quoted in the EIS is an example of a range that could be used to trigger certain actions. The example used in the EIS assumes that an increase of 50% over the baseline level could act as a trigger or action level. Hence the trigger level could be 22 µg/L in autumn and 63 µg/L in the summer.

What the EIS section 2.7 “Trophic Status Discussion” is proposing is that the Canadian Guidance Framework for the Management of Freshwater Systems published by the Canadian Council of Ministers of the Environment, 2004 (CCME,2004) will be used to as a resource to develop the trigger, alert and action levels as well as provide a framework for an adaptive management plan for TP concentrations. Critical TP concentration levels that would precipitate mitigation actions have not been determined at this time. Trigger levels will be determined as part of an overall water management monitoring and mitigation plan that will be assembled using the CCME,2004 as a guide and with input from the BC Ministry of Environment during permitting. The monitoring and management of TP concentrations will form one part of a comprehensive plan to conserve the trophic status and overall ecology of Fish Lake.

Information Request #25b

Clarify what fraction of P is being used in the (Productivity) analysis or if total phosphorus (TP) is the metric being considered?

Summary

The Fish Lake productivity analysis utilized TP for the calculation of the Fish Lake phosphorus budget. The productivity metrics that were used to calculate the Carlson trophic indices included *chlorophyll a* concentrations, TP concentrations and secchi depth.

Discussion

The BATHTUB productivity model represents an interface platform from which multiple empirical and mechanistic models are run. During the calibration process, many physical and chemical parameters that describe the atmospheric loads, in-lake water quality parameters, water quality of the tributaries as well as morphological characteristics of Fish Lake and tributaries were entered into the model (see Table 2, *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS). In total, two phosphorus species were entered into the BATHTUB productivity model, these included Total Phosphorus (TP), and Ortho-phosphate (PO_4^{3-}).

The first step of the model involves the calculation of a lake water balance that includes a hydraulic residence time. The second stage involves calculating the chemical mass balances for the lake. For this purpose, the empirical formulas presented by Vollenwieder (1975 and 1976) were used. These formulas utilized TP for the calculation. The third step of the BATHTUB modelling process involved predicting the water quality parameters (PO_4^{3-} , Carlson indices, algal biomass (*Chlorophyll a* concentrations) and transparency (Secchi depth) of Fish Lake. This was done using a series of empirical models or algorithms contained in BATHTUB (Refer to Section 2. 4 of the *Fish Lake Productivity Report*, Appendix 2.7.2.4B-A of the New Prosperity Project EIS). These *Chlorophyll a* concentrations were used to predict Dissolved Oxygen (DO) depletion in the water column. The final stage of the modelling process was to evaluate the trophic response of the lake, which was done by using indices reported by Carlson (1977). The Carlson trophic indices (CTI) places the predicted TP, *Chlorophll a* and secchi depth onto a common trophic scale for evaluation of predicted changes to trophic conditions. For example

TP CTI = eutrophic

Chlorophyll a CTI = mesotrophic

Secchi depth CTI = oligotrophic

Conclusion

The Fish Lake productivity analysis utilized TP for the calculation of the Fish Lake phosphorus budget. The productivity metrics that were used to calculate the Carlson trophic indices included *chlorophyll a* concentrations, TP concentrations and secchi depth.

Information Request #25c

Discuss the likelihood of Fish Lake experiencing acute seasonal limitation of nitrogen in the surface water and the decision to monitor and implement mitigation measures.

Response Summary

There will be several factors that have the potential to change and influence the TN:TP ratio in Fish Lake. The predicted concentrations of TP are not expected to deviate from within the wide range of baseline P concentrations observed in Fish Lake, leaving us with factors that could affect the TN concentrations. No changes in the incoming TN:TP ratios from natural runoff are expected as a result of changes to watershed size or composition. Recirculation may tend to favour a decrease in the TN:TP ratios, due to the denitrification of recirculated water. However, this will be compensated for by algal N fixation during the growing season. Several water quality parameters have also been examined that could affect algal nitrogen fixation and subsequently the TN:TP ratio. Some of the changes in quality could favour algal nitrogen fixation while others could reduce the efficiency of fixation. Acute seasonal limitation of nitrogen in the surface water is not expected, however monitoring of the aquatic ecosystem will be implemented and if needed, adaptive management techniques will be employed to assure its ongoing health.

Discussion

Current Conditions at Fish Lake

The condition of N limitation refers to a condition whereby the total nitrogen to total phosphorus ratio (TN:TP) is below the classic Redfield molar ratios of 16: 1 (N:P) described by Alfried Redfield (Redfield 1935). In reality different aquatic species with different niche habitats exhibit a variety of values above and below 16:1. The Fish Lake Baseline N data (Appendix 5-2-A) showed that the lake wide average of total ammonia, nitrate and nitrite are 0.09, 0.0184 and 0.00175 mg/L, respectively (total 0.110 mg/L). No data was collected for organic nitrogen making it impossible to calculate the true TN concentration. Conversely, the baseline water quality analysis consistently included Total Phosphorus (TP), which provided us an average lake wide TP concentration of 0.069 mg/L (Appendix 5-2-A). If one were to calculate the TN:TP concentration from this baseline data, while excluding the organic N contribution, the ratio would equal approximately 1.6:1, suggesting a severe N limitation.

Additional water samples collected from Fish Lake in the summer, fall and winter of 2011/2012 did include analysis of both TN as well as TP concentrations (Appendix 2.4.2.4B-C). During these sampling surveys the average TN concentrations in the summer, fall and winter were 0.546, 0.649, and 0.872 mg/L, respectively. These concentrations are significantly greater than the total value of 0.110 mg/L calculated without organic nitrogen, suggesting that organic nitrogen is an extremely important component of the overall TN concentration. When the TN concentrations observed in 2011 and 2012 are compared with the average TP concentrations observed during the same period (0.036 mg/L summer, 0.037 mg/L fall, 0.040 mg/L winter) the TN:TP ratio ranges between 15.17 and 21.71. These values are more consistent with the established ratio of 16:1.

We believe that this omission in the original baseline data in Appendix 5-2-A could be the source of some of the argument surrounding the potential for N limitation as opposed to P limitation in Fish Lake. It is highly recommended that a full suite of N species (NO_2^-, NO_3^-, Total Ammonia, Organic Nitrogen (ON) and TN be evaluated in future sampling programs in Fish Lake.

<u>Likelihood of Future N Limitation</u>

1) In regards to the factors that could lead to "acute seasonal N-limitation in the surface waters of Fish Lake" in the future there are two factors that could cause change. The first is the effect of the contributing watershed decreasing and the second is the effect of water chemistry change.

Contributing Watershed Will Decrease

The water management plan in the EIS indicates that the contributing watershed around Fish Lake will be reduced by approximately 60% during the construction and operational phases of the Project. The planned reduction in the catchment area will change the total amount of influx of both TN and TP to Fish Lake. In this situation, both elements will likely be reduced by equal proportions leaving the ratio between TN:TP unchanged.

The watershed that will be lost, underneath the TSF, includes areas of forested uplands, swamps, shrub-carr and fen environments as well as Little Fish Lake. Based upon the existing literature it would not appear that these sites would contribute largely to either the P or N budgets of Fish Lake as all of the sites would appear to be net sinks for nitrogen in the environment. Forested areas have been shown to be nitrogen sinks that effectively and efficiently utilize nutrients that enter the environment from mineral weathering, atmospheric deposition, and precipitation (Campbell et al. 2004). Similarly, saturated forest soils and (Flite et al. 2001) and wetlands (Jacks et al. 1994) appear to be net sinks for nutrients during the growing season through biotic uptake, and as a result of denitrification throughout the year. Of the remaining contributing watershed, no changes to the land cover or vegetative community is planned. The proponent's efforts will ensure that non-contact water are diverted around mine infrastructure and any water that does come in contact with infrastructure or stockpiles will be transported to the TSF. As a result, no change in TN:TP ratio entering Fish Lake is expected as a result of the reduction in watershed size or changes in land use within the catchment area.

Finally, because the fish populations in Fish Lake will require supplemental flow in the inlets of the lake to support spawning activities, continuous re-circulation will be required from the outlet back up to the inlets. This arrangement will provide additional opportunities for some of the N to be lost from the system through the process of denitrification as the water recirculates back through the saturated margins of the channels and lake. Phosphorus is not subject to this process and hence could increase in relation to N, potentially leading to a situation of nitrogen limitation. However both P and N will be lost in equal proportions from Fish Lake through the pumping of excess water from the outlet of the Lake to the TSF/open pit during operations/closure. Additionally, there may be a permanent loss of P to the sediments of Fish Lake that has been measured and reported in Appendix 2.7.2.4B-B. Permanent loss of N to sediments was not quantified in this study; however some permanent N scavenging to sediments can be expected (Scott and McCarthy 2010). Overall the process of recirculation would tend to favour the decrease in TN:TP, however we believe that this will be internally corrected in Fish Lake through the process of algal nitrification (see the section in this discussion on Nitrification Fixation).

Changes in Water Chemistry

Based upon the proposed arrangement of the New Prosperity Mine, some changes to water chemistry to Fish Lake are expected. Modelling has been carried out and predicted results suggest that the worst case P concentrations will range between 0.034 and 0.066 mg/L in the epilimnion and between 0.185 and 0.257 mg/L in the hypolimnion (Table 25C-1). These concentrations are within the range of concentrations observed in the baseline study at 0.002 and 0.320 mg/L (mean 0.069 mg/L) (Appendix 5-2-A). A more recent study (Appendix 2.7.2.4B-C) suggested that the lake contained less P, ranging between 0.027 and 0.057 mg/L, however this study consisted of only three sampling visits and may have missed a short lived P spike if one had occurred. Overall, the data suggests that P concentrations will stay within the observed baseline range. So N limitation is not expected to occur through the increase of P concentrations.

Table 25C-1. Maximum Predicted P concentrations. Source Appendix 2.4.2.4B-C

Period	Project Phase	Epilimnetic P conc.	Hypolimnetic P conc.
October to June	4	0.066	0.246
July	4	0.034	0.246
August	4	0.036	0.257
September	4	0.048	0.185

In addition to predicted changes to P concentrations other elements are predicted to change in Fish Lake (Table 25C-2). Some of these changes could favour algal nitrogen fixation while others could reduce the efficiency of fixation. Micronutrients such as Iron (Fe) (Wurstbaugh and Horne 1983) and Molybdenum (Mo) (Howarth et al. 1988b) have been identified as potential secondary limiting elements. Water quality predictions in Fish Lake suggest that the concentrations of Mo are expected to increase which would favour the fixation of N in the lake. Alternatively, the mean concentrations of Fe are expected to remain fairly unchanged, while the maximums are predicted to decrease, which could decrease the efficiency of N fixation within the lake. Sulphate (SO_4^{2-}) is expected to increase during all phases of the project. Sulphate has been identified as a potential inhibitor of molybdenum uptake and hence nitrogen fixation in oxic environments (Howarth et al. 1988b). This same inhibition however, is not expected in the lower oxygen environments of the sediments and hypolimnion (Howarth et al. 1988b).

Table 25C-2. Predicted changes in water quality variables linked to the increase and decrease of N fixation in fresh water lakes.

Phase		Iron	Molybdenum	Sulphate
Baseline	Mean	0.43	0.00028	1.028
	Max	2.43	0.00033	3.50
1	Median	0.31	0.0079	20.52
	Max	0.41	0.0263	63.30
2	Mean	0.36	0.0085	29.92
	Max	0.44	0.0177	70.07
3	Mean	0.35	0.0015	21.95
	Max	0.47	0.0056	58.63
4	Mean	0.47	0.0037	74.83
	Max	0.74	0.0063	138.4

Finally, it has been shown that the efficiency of N fixation is determined by the productivity of the lake. Eutrophic systems may fix N more efficiently (Howarth et al. 1988a) and hence are better equipped to achieve and maintain a stable TN:TP ratio. At baseline, Fish Lake could be considered a eutrophic system (Mean TP=0.069 mg/L) (Appendix 5-2-A). Water quality predictions during the life of the mine and beyond do not suggest that there will be a decrease in the productivity of the lake, as such it would be expected that the organisms in the lake would continue to operate efficiently to fix atmospheric N and maintain a stable TN:TP ratio.

A General Review of Nitrogen Fixation

Primary producers in aquatic ecosystems require several macro-nutrients to grow and reproduce. These include Carbon (C), Hydrogen (H), Nitrogen (N), Oxygen (O), Phosphorus (P) and Sulphur (S). With the exception of P, all of these macro nutrients are available to the aquatic environment in gaseous form from the atmosphere. When aquatic productivity is discussed, the elements of interest generally focus on N and P.

Nitrogen may enter lakes in several different ways. First, N may enter via atmospheric deposition and precipitation. This occurs though the reaction of gaseous nitrogen oxides (NO_x) and water in the atmosphere forming nitric acid which is deposited directly on the lake surface. Second, N may enter the lake through runoff from the surrounding watershed. Nitrogen in this form can be in inorganic and organic forms and is collectively is known as allochthonous inputs. Finally, nitrogen can be fixed directly from the atmosphere by nitrogen fixing bacteria, the most important of which are the cyanobacteria (Howarth et al. 1988a).

The relative importance of each N source within a particular lake is primarily determined by the watershed characteristics, climate, and trophic status of the lake. Simply put, in an N rich watershed allochthonous inputs will contribute more of the total N budget. Lakes within an area that have high concentrations of atmospheric nitrogen oxides will have greater amounts deposited from the atmosphere. Finally, eutrophic lakes characteristics (ie. high rates of productivity) will exhibit higher rates of nitrogen fixation as opposed to oligotrophic and mesotrophic lakes (Howarth et al. 1988a). Detailed elemental budgets have shown that the N fixing bacteria in a eutrophic lake can fix between 6 and 82% of the total lake N budget equating to between 0.1 and >90Kg per hectare (Howarth et al. 1988a, Howarth et al. 1988b).

Due to the lack of a gaseous form of P, the only way P may enter the lacustrine environment via allochthonous inputs either is via surface runoff or as wind-blown particulates. This means that in the absence of anthropogenic inputs, the P concentrations in all lakes are largely influenced by the watershed characteristics. This may be one of the primary reasons for the large amount of variability observed in aqueous P concentrations and productivity in natural lakes.

Whole lake experiments carried out at the Experimental Lakes Area in Northwestern Ontario demonstrated that P not N is the primary limiting nutrient in most freshwater aquatic ecosystems (Schindler 1977). The principal outcome of the (Schindler, 1977) research showed that the overall algal productivity was “proportional to the concentration of phosphorus”. Furthermore, the author confirmed, through N:P manipulation studies, that in the situations where N was theoretically limiting, N fixing bacteria rapidly became the dominant algal species. This in turn will lead to a situation whereby the “fixation of nitrogen accounted for a substantial proportion of the total income of nitrogen into the lake” and adjustment back to a N:P representative of other lakes in the area.

Following a period of approximately 6 years manipulating the nutrients in an experimental lake with both P and N (Schindler 1977), the author began to reduce the proportion of N in the fertilizer over a thirty one year period (1975-2006) to evaluate how the trophic status of the lake changed. During the final 16 years of this study the lake was treated with P fertilizer only (Schindler 2008). As expected, this study demonstrated that the artificial reduction in TN to TP ratio (TN:TP) favoured the establishment of N-fixing cyanobacteria (Schindler 2008). Additionally, Schindeler study showed that N fixation in a lake was efficient enough to supplement any N limitation and in effect, allow the overall productivity of the lake to remain proportional to the P concentrations in the ecosystem (Schindler 2008).

Subsequently, it was noted by Scott and McCarthy (2010) that actually the TN:TP ratio had consistently decreased during the N phase out portion of this experiment (1975 – 1990). Additionally they reported a consistent decrease in Chlorophyll *a* concentrations between 1997 and 2005, beginning seven years after the switch to P only fertilization (Scott and McCarthy 2010). This would suggest that N fixation is not always capable of bringing the ratio of Total Nitrogen to Total Phosphorus (TN:TP) and hence primary productivity may be limited by a combination of P and N (Scott and McCarthy 2010). However, it should be noted that N fixation was capable of maintaining the equilibrium during the earlier stages of the experiment despite the fact that the proportions of N and P in the fertilizer were slanted towards N limitation (Schindler, 2008). One thing that was not disputed by these authors was the fact that productivity remained elevated and the lake remained eutrophic through the experiment, despite apparent N limitation at times during the later parts.

Monitoring and Adaptive Management

Monitoring and adaptive management will be an important part of the strategy to manage Fish Lake following the development of the mine. In addition to the standard water quality variables (including nutrients and organic nitrogen), which could be regarded as surrogates describing the health of the aquatic ecosystem, the program will measure the direct biological expression of the water quality, the algal community composition and productivity. This will provide an indication of the changing composition of the community, and provide valuable insight into the true expression of the TN:TP ratio. For example, if the algal community is dominated by N fixing cyanobacteria or blue-green algae that compete well in N limited environments (eg. *Microcystis*), we can assume that the lake is N limited. If this situation persists mitigation may be required.

The final decision upon adaptive management as well as the direction any management would take would be determined by a Fish Lake water quality technical working group. If mitigation were required, techniques would likely involve reducing the P load to the lake. This would address two potential problems; first, it would reduce the TN:TP ratio towards the re-establishment of a healthy ratio and second, it would help to reduce the natural eutrophic conditions present at the lake.

Conclusion

There will be several factors that have the potential to change and influence the TN:TP ratio in Fish Lake. The predicted concentrations of TP are not expected to deviate from within the wide range of baseline P concentrations observed in Fish Lake, leaving us with factors that could affect the TN concentrations. No changes in the incoming TN:TP ratios from natural runoff are expected as a result of changes to watershed size or composition. Recirculation may tend to favour a decrease in the TN:TP ratios, due to the denitrification of recirculated water. However, we believe that this will be compensated for by algal N fixation during the growing season (see Review of Nitrogen Fixation process at the end of this write up).

Several water quality parameters have been examined that could affect algal nitrogen fixation and subsequently the TN:TP ratio. Several of the factors could increase the efficiency with which N may be fixed by the algal community (eg. increased Mo, maintenance of eutrophic state) while others could negatively impact the efficiency of N fixation (eg. increased SO_4^- concentrations). At the end of the day, SO_4^{2-} concentrations could impede the efficiency of N fixation within the oxic epilimnion of the lake by inhibiting the assimilation of trace elements required by N fixing bacteria. However, this inhibition is not expected in the hypolimnion and sediments due to the presence of increased dissolved iron and stable reduced forms of molybdenum. Based upon this assessment, it would appear that P is most likely the primary nutrient limiting algal productivity in Fish Lake and there is a low likelihood of nitrogen limitation in Fish Lake. However monitoring of the aquatic ecosystem will be implemented and if needed, adaptive management techniques will be employed to assure its ongoing health.

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Information Request #25d

Provide Information regarding what other important lake water quality variables will be monitored to assess the need for mitigation against eutrophication (eg. measures of nutrient limitation such as TN:TP, POC:PON)

Response Summary

Specific variables that will be monitored to determine the trophic state of Fish Lake have yet to be determined. Typically a comprehensive suite of water quality variables would be monitored to assess the need for mitigation against eutrophication. These variables would be specified as part of the Mines Act Permit. Monitoring would likely focus special attention on phosphorus, which has been demonstrated to be the primary limiting nutrient in aquatic systems. It is expected that there would also be evaluations on direct measures of productivity in the form of detailed planktonic, invertebrate and fisheries monitoring throughout the life of the mine. Monitoring a wide variety of water chemistry variables will probably be utilized to ensure that the nutrients in the lake stay at a healthy balance for all aquatic creatures.

Discussion

It is anticipated that a full suite of water quality and biological parameters will be monitored to assess the need for mitigation against eutrophication. Specific water quality parameters that are typically monitored are detailed in Table 25D-1. Specific biological parameters that are usually monitored are detailed in Table 25D-2.

Table 25D-1. Water quality parameters

Physiochemical	**Nutrients**	**Inorganics**
TSS (mg/L)	Total Phosphorus (mg/L)	Common anions (mg/L)
TDS (mg/L)	Diss. Phosphorus (mg/L)	Dissolved Metals (mg/L)
Conductivity (µS/cm)	Nitrate (mg/L)	Total Metals (mg/L)
TOC (mg/L)	Nitrite (mg/L)	
DOC (mg/L)	Ammonia (mg/L)	
Hardness (mg/L)	Organic Nitrogen (mg/L)	
Alkalinity (mg/L $CaCO_3$)		

Table 25D-2. Biological parameters

Zoo and Phytoplankton	**Invertebrates**	**Fish**
Community Structure	Community Structure	Community Structure
Biomass	Biomass	Spawning Success
		Metals in Tissue
		Overall health (parasites/diseases)

The primary water quality parameter monitored to evaluate the need for mitigation against eutrophication is usually phosphorus. This is because phosphorus has been shown to be the primary limiting nutrient in aquatic environments. In addition to monitoring “proxy” productivity variables, such as phosphorus, Taseko will directly measure changes in productivity by evaluating the planktonic, invertebrate and fish populations and communities in the lake.

Recognizing that healthy system requires more than simply phosphorus, Taseko will be monitoring a full suite of other nutrient variables, such as nitrogen and organic carbon. These values may be utilized to calculate a wide array of ratios that are used to ensure that nutrients remain at a healthy balance in the system.

Information Request #25e

Provide an assessment of potential impacts of changes in ecosystem productivity that could occur in conjunction with changes in hydrology, physio-chemical inputs (such as turbidity, nutrients, temperature, chlorophyll) as well as the synergistic impact of the dissolved metals likely to enter the system.

Response Summary

Due to the broad nature of this question we have tried to point interested reviewers in the direction of appendices and responses that may cover aspects of this question. Beyond this, the dynamic physical, chemical and ecological factors and interactions that contribute to the productivity of a lake remain too complex to fully interpret. If the reviewers have specific questions beyond those covered in the listed resources, Taseko would be happy to address them to the best of our ability.

Discussion

This is an extremely broad question requiring all of the possible factors that can influence productivity, many of which have been previously discussed and considered in submitted documents or other information requests. Instead of re-iterating all the relevant information that has been presented, we have divided the factors into the three main categories listed in the question.

1. Changes in ecosystem productivity relating to changes in hydrology
2. Changes in ecosystem productivity relating to changes from physio-chemical inputs
3. Changes in ecosystem productivity relating to changes in metals concentrations

Based upon our interpretation of the question we have attempted to identify all of the relevant sources of information and discussions pertaining to that specific factor.

1. Changes in ecosystem productivity relating to changes in hydrology are discussed in;
   - ***Appendix 2.7.2.4B – Fish Lake Productivity Model Report*** – Comprehensively discusses nutrients, changes in hydrology and overall productivity
   - **Information Request #19c –** Discusses how re-circulation could affect N cycling
   - **Information Request #19d –** Discusses how the loss of wetland habitat will affect nutrients and productivity
   - **Information Request #25c** – Discusses the likelihood of Fish Lake exhibiting N limitation as a result of the proposed configuration

2. Changes in ecosystem productivity resulting from physio-chemical inputs are discussed in;

    - ***Appendix 2.7.2.4B – Fish Lake Productivity Model Report –*** Comprehensively discusses nutrients, changes in hydrology and overall productivity,
    - ***Appendix 2.7.2.4B-D – Mitigation Flow –*** Discusses how temperature and dissolved oxygen may be affected in mitigation creeks,
    - **Information Request #19b –** Discusses total N concentrations and fish productivity in Fish Lake,
    - **Information Request #19c –** Discusses how re-circulation could affect N cycling in Fish Lake and its watershed,
    - **Information Request #19d –** Discusses how the loss of wetland habitat will affect nutrients and productivity in Fish Lake,
    - **Information Request #19e –** Discusses phosphorus loading in fish lake and its watershed and how this may affect productivity,
    - **Information Request #25c –** Discusses the likelihood of Fish Lake exhibiting N limitation as a result of the proposed configuration

3. Changes in ecosystem productivity resulting from the synergistic inputs of dissolved metals are discussed in;

    - ***Appendix 2.7.2.4B-E – Biotic Ligand Model –*** Discusses the potential impacts on the aquatic environment resulting from the predicted concentrations of Copper, Cadmium and Silver in Fish Lake as well as other mixing points. This report takes into account matrix effects and synergistic interactions.
    - ***Appendix 2.7.2.4B-F – Water Quality Modelling*** – Discusses all predicted metal concentrations in Fish Lake Tributaries, Fish Lake, the TSF, and Pit Lake in relation to the appropriate provincial and federal guidelines. In situations where guidelines are dependent on other factors (i.e., Lead and hardness), specific guidelines were calculated.
    - ***Appendix 2.7.2.4B-G – Water Quality Model*** – Discusses all predicted metal concentrations in Lower Fish Creek, Beece Creek, Little Onion Lake, Big Onion Lake, and Wasp Lake in relation to the appropriate provincial and federal guidelines. In the situations where guidelines are dependent on other factors (i.e., Lead and hardness), specific guidelines were calculated.

Beyond the Biotic Ligand Model (applied for Copper, Cadmium, and Silver) no other modelling approaches were found that could accurately evaluate the expected effects on productivity as a result of the predicted water quality. Developing this type of site specific guideline model requires extensive laboratory toxicity testing and natural ecosystem manipulation to calibrate. The principal problem is that natural processes are highly dynamic and complex; there are limitless possible combinations of site specific conditions that could impact the ultimate expression of the predicted water quality. The Experimental Lakes Area in Northwestern Ontario was beginning to unravel some of these relationships and factors using a whole lake study approach. Unfortunately, this valuable program has recently been slated to close by Fisheries and Oceans Canada prior to answering the myriad of possible questions that could be asked regarding the synergistic effects of dissolved metals. Even if some of the questions had been evaluated at the Experimental Lakes Area the site specific conditions that exist at Fish Lake would inevitably lead to variability from the results observed during controlled experiments.

Information Request #25f

Provide a discussion on the potential effects of aeration as a mitigation measure on the lake system as well as the effectiveness of the mitigation measures proposed in the EIS, including any documented success of this mitigation measure.

Response Summary

Hypolimnetic oxygenation has successfully been employed as a mitigation measure to address concerns including hypolimnetic anoxia, elevated internal nutrient loading, and potentially harmful levels of sulphides and ammonia.

Discussion

As a potential mitigation measure, hypolimnetic oxygenation may be employed at Fish Lake. If it is implemented there will be at least three objectives of the aeration project.

1) To increase the hypolimnetic dissolved oxygen concentrations to reduce the likelihood of fish kills and to improve the habitat for cold water species (ie. Rainbow Trout)

2) To limit the extent of internal eutrophication by limiting anaerobic reduction of accumulated nutrients in sediments, thereby reducing internal nutrient loading to the hypolimnion.

3) To limit the amount of reduced chemical species (eg. hydrogen sulphide, Ammonia) in the hypolimnion

Although there are a number of aeration systems currently available for use in Fish Lake, a full lift hypolimnetic oxygenation system would be most likely. This system pumps cold water from the hypolimnion of the lake to the surface where it is oxygenated with pure oxygen and pumped back to the hypolimnion of the lake. This method offers several benefits over other aeration schemes;

<u>Benefits</u>

1) A full lift hypolimnetic oxygenation system will not cause the lake to de-stratify, which has several important benefits

    a. It will preserve the cold waters in the hypolimnion for cold water adapted species.

    b. It will provide the inlet stream water recirculation system with cold water to adjust the temperatures during spawning and incubation if necessary

    c. It will prevent the mixing of the nutrient rich hypolimnion waters with the productive epilimnetic waters, thereby reducing the likelihood of elevated productivity

2) A full lift hypolimnetic oxygenation system is less likely to bring about a situation of nitrogen supersaturation in the hypolimnion as it employs pure oxygen, as opposed to compressed air which contains nitrogen.

3) It provides improved O_2 transfer efficiency to the water, as opposed to atmospheric air, which in turn reduces the amount of circulation that is required as well as the potentially de-stratifying turbulence in the hypolimnion.

4) It has been found to lead to lower amounts of induced oxygen demand in the hypolimnion of lakes as opposed to other hypolimnetic aeration techniques

Hypolimnetic oxidation has been used in many situations to mitigate problems such as hypolimnetic anoxia, internal phosphorus loading and elevated concentrations of reduced compounds. There are many examples of these types of systems that have been employed around the world on a variety of waterbodies.

Table 25F-1. Projects in which hypolimnetic oxygenation have been employed (Summarized from Beutel and Horne, 1999)

Location	Size	Synopsis	Citation
Ottoville Quarry	z_{mean} = 8.7 m v = 6.3 x 10^4 m^3	Able to maintain hypolimnetic O_2 concentrations of 8 mg/L	Fast *et al*. (1975)
Lake Baldegg	z_{mean} = 33 m v = 1.7 x 10^8 m^3	Culturally eutrophied lake treated with O2 to reduce internal P loading and hypolimnetic concentrations of ammonia and manganese	Imboden (1985)
Richard B Russel Lake	z_{mean} = 12 m v = 1.3 x 10^9 m^3	Degraded Reservoir water treated to maintain water at a suitable quality for hypolimnetic water release downstream	James *et al.* (1985)
Amisk Lake (Alberta)	z_{mean} = 14.5 m v =8.0 x 10^7 m^3	Culturally eutrophied lake was treated to reduce internal P loading, hypolimnetic ammonia concetrations and summer phytoplankton growth	Prepas et al. (1997) Prepas and Burke (1977)
Location	**Size**	**Synopsis**	**Citation**
Newman Lake	z_{mean} = 6.0 m v = 2.8 x 10^7 m^3	Culturally eutrophied lake was treated to reduce elevated levels of productivity and poor water quality	Thomas (1994)
Douglas Dam	v = 1.7 x 10^9 m^3	Reservoir treated to increase DO concentrations and reduce H_2S concentrations in discharged water	Mobley and Brock (1995)
Commanche Reservoir	z_{mean} = 17 m v = 5.1 x 10^8 m^3	Reservoir treated to increase DO and reduce H_2S for release to fish hatchery	Horne (1995)

For additional information on hypolimnetic oxygenation projects as well as other aeration schemes see Nordin and McKean (1982)

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Information Request #25g

Provide a clarification on the length of time that re-circulation of flows to Fish Lake would be required.

Response Summary

For the purpose of water quality modelling, the length of time that the water from Fish Lake is re-circulated is 100 years. However, if actual conditions are conducive, recirculation may have to take place for as little as 49 years. It is dependent upon the time it takes for the water in the tailings storage facility (TSF) to reach a quality that is acceptable for discharge into the Fish Lake inlets. It is also dependent upon the time needed for the Pit Lake to fill and become viable fish habitat. Once both of these conditions are met and the fish spawning habitat north of the Pit Lake outlet is again provided with run off from Pit Lake, recirculation will be shut off. The sequence of water routing is described in the discussion section below.

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

Note that the timing of the two Closure Phases is not definite. The times quoted above are the times used in the water quality models. However, as will be explained below, if actual water qualities differ from the model, the Closure Phase times will change.

<u>*Construction Phase*</u>: 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. Excess water not required as supplemental flow in the Fish Lake inlets will be pumped to and stored in the TSF.

<u>Operations Phase I:</u> Fish Lake outflow continues to be recirculated to the Fish Lake inlets with excess water being pumped to and stored in the TSF.

<u>Operations Phase II</u>: Fish Lake outflow continues to be recirculated to the Fish Lake inlets. Excess water not required for supplemental flow into Fish Lake 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.

<u>Closure Phase I</u>: Fish Lake outflow continues to be recirculated to the Fish Lake inlets. Excess water not required for supplemental flow into Fish Lake will be directed to the open pit. Although some 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. Excess water in the TSF will also report to the open pit. For the purposes of water quality modelling, it was assumed that the excess water in the TSF at the end of this phase would be of a quality that would allow discharge into Fish Lake. The year in which this phase finishes could change depending on the actual amount of time required for the TSF water to reach a quality acceptable for discharge to the lake.

<u>Closure Phase II</u>: For the purpose of water quality modelling, the Fish Lake outflow continues to be recirculated. Excess water not required for supplemental flow into Fish Lake 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. For the purposes of water quality modelling, it was assumed that the excess water in the TSF at the beginning of this phase would be of a quality that would allow discharge into Fish Lake. The year in which this phase begins could change depending on the actual amount of time required for the TSF water to reach a quality acceptable for discharge to the lake.

<u>Post Closure Phase</u>: Water has completely filled the open pit and is now discharging to Lower Fish Creek. The fish barrier between Fish Lake and the open pit will remain in place until the water in the Pit Lake is of a quality that will support fish habitat. Once fish have access to the Pit Lake, the fish spawning habitat in the lower reaches of Fish Creek will be restored. There will also be additional spawning habitat associated with the Pit Lake. Overflow from the TSF is now reporting to the Fish Lake inlets. This flow combined with natural run off will restore the flows in the fish lake inlets to pre-project levels and the need for recirculation will no longer be needed.

Conclusion

For the purpose of water quality modelling, the length of time that the water from Fish Lake is re-circulated is 100 years. However, if actual conditions are conducive, recirculation may have to take place for as little as 49 years. It is dependent upon the time it takes for the water in the tailings storage facility (TSF) to reach a quality that is acceptable for discharge into the Fish Lake inlets. It is also dependent upon the time needed for the Pit Lake to fill and become viable fish habitat. Once both of these conditions are met and the fish spawning habitat north of the Pit Lake outlet is again provided with run off from Pit Lake, recirculation will be shut off.

Information Request #25h

Provide a discussion of the temporal and spatial scale for monitoring and maintenance of flow augmentation in order to maintain spawning habitat in the tributaries and maintain Fish Lake water balance and trophic status.

Response Summary

Definitive flow augmentation monitoring locations and recording periods have not been determined. As is normal course, the specific monitoring equipment, placement, frequency and reporting methods will be incorporated into adaptive management plans that will be developed through the permitting process. Conceptual plans for the monitoring and maintenance of the Fish Lake flow augmentation are discussed below.

Discussion

Currently all streams in the Fish Lake water shed are ephemeral. During the project, spawning tributaries, Reach 8 and Fish Lake Tributary 1, will be augmented with recirculating flows from Fish Lake throughout every year to provide perennial habitat during life-of-mine and at closure until such time that Fish Lake is fully functioning (i.e., maintaining a self-sustaining population of Rainbow Trout without spawning flow augmentation in upper Fish Creek watershed). Post-closure natural flow volumes will be restored to downstream habitats to enable restoration of natural flow regimes and productive habitat use.

Flow augmentation volumes were calculated based on existing discharge information, channel morphological data, and available habitat suitability data, specifically, mitigative flow augmentation will be adaptively managed to ensure that appropriate water depth, temperature, and dissolved oxygen levels meet the requirements for the life stages present. Specific details on the mitigative flows are provided in *Fish Lake Mitigation Flow* Technical Appendix (Appendix 2.7.2.4B-D) of the EIS Application (September 2012).

Flow monitoring stations (relative water depth (m); discharge (m^3/s)) will be established in Reach 8 and Fish Lake Tributary 1. Potential locations would likely include:

- at/near their respective pump outlets (headwaters);
- at locations approximately 1.0 km upstream from their respective Fish Lake confluences, and
- at their respective confluences with Fish Lake.

The spatial separation of the flow monitoring stations will enable site-specific identification of disruptions to flow (e.g., seepage escapement flows, beaver dam construction, naturally occurring de-watering areas). It is also anticipated that flow monitors will be placed on the pumps and along the pipelines to detect leaks between the pumps and the respective pump outlets.

Data from the flow monitoring stations would typically be recorded and analyzed continuously (data logger) throughout life-of-mine and at closure. Real time monitoring would issue alarms when disruptions to flow are detected and appropriate measures would be applied.

Rainbow Trout spawner abundance and density, female fecundity, spawning success (egg-fry-survival), and juvenile outmigrations from each augmented tributary would likely be determined and assessed on a seasonal basis to better define flow requirements specific to the upper Fish Creek watershed population. Growth rate and condition factor of the Fish Lake populations of immature adult and juvenile Rainbow Trout would be assessed during late summer throughout the life-of-mine and at closure to better define carrying capacity targets and goals in the upper Fish Creek watershed.

Pumps and pipelines will be designed to handle more than the required flows and back up pump systems will be in place to guarantee continuous and uninterrupted flow to the Fish Lake tributaries. Backup generators will be installed that will automatically engage in the event of a power outage.

Conclusion

Monitoring and maintenance of the Fish Lake tributary flow augmentation would be set up to allow mine personnel to react quickly and effectively to any disruption to flows. Redundancies and back- up measures will be built into the overall system to provide uninterrupted flows through-out the life of the project until the Fish Lake ecosystem can support a self-sustaining population of rainbow trout without flow augmentation.

Information Request #25i

Provide details of the adaptive management goal for Fish Lake along with adaptive management options available that would ensure Fish Lake and its tributaries remain a biologically functioning ecosystem.

Response Summary

The overarching goal of the adaptive management program will be to maintain a habitat capable of supporting a viable population of rainbow trout during the life of the mine, achieving a self-sustaining rainbow trout habitat in the post closure period. There are well understood, proven technologies used in a variety of applications that will adjust the physical, chemical and biological states of water bodies and aquatic ecosystems. Taseko will apply the appropriate technology to adjust the Fish Lake trophic state if/when monitoring results indicate that the threshold levels in the adaptive management plans are being approached.

Discussion

As indicated in Information Request IR 25(j), Taseko is committed to regular monitoring and follow-up programs to assess Fish Lake and/or its tributaries for:

- water chemistry (nutrients, dissolved oxygen, dissolved metals, pH and temperature);
- physical habitat in flow-augmented tributaries (discharge, access (beaver activity), pool depth and adequacy, bank stability and spawning gravel quantity and quality); and,
- biological parameters, including fish health (metals accumulations, parasites, condition factor and disease), spawner, emergent fry and juvenile populations, invertebrate (pelagic and benthic) populations and species diversity

Some of the adaptive management options available for mitigation against significant adverse effects to the Fish Lake ecosystem include:

a) Nutrient Levels:

   - Phosphorus and Nitrogen addition or removal.
   - Constructed wetland treatment
   - Periphyton treatment
   - Phosphate precipitation.
   - Ozone treatment
   - Aeration

b) Metal Levels:

- Water Treatment
- Reverse Osmosis
- pH adjustment water treatment systems
- Electro-coagulation water treatment systems.

c) Dissolved Oxygen:

- Mechanical aeration
- Construct water features that would naturally aerate the water flow

d) pH:

- pH adjustment water treatment systems (Sodium carbonate / Calcium hydroxide).

e) Temperature:

- Adjust water intake depth to recirculation pumps
- Mechanical temperature control of recirculating water

f) Water Discharge:

- Adjust number of pumps
- Adjust pumping rates
- Adjust amount of water going to the TSF as opposed to recirculation

g) Fish Access

- Remove fish barriers, beaver dams, etc.

h) Pool Depth

- Artificial pool creation
- Improve pool outlets, riffle crest depths and adjust invert elevations

i) Spawning Gravel:

- Add gravel as required

- Adjust gravel size and depth

j) Bank Stability

- Stabilize banks as required
- Tree planting

k) Fish Health (parasites/diseases)

- Adjustment of ecosystem components causing changes in health

l) Fish Health (metals accumulation):

- Water treatment commensurate with metals accumulation

m) Spawning Population

- Construction of artificial spawning grounds
- Farming of trout from Fish Lake in an offsite hatchery.

n) Invertebrates (benthic and pelagic)

- Adjustment of ecosystem components causing changes in invertebrate survival.

Information Request #25j

Describe the thresholds that have been established for adaptive management of Fish Lake and provide a rationale on how these thresholds were determined.

Response Summary

Threshold levels for determining when mitigation measures need to be implemented have not been established. As is the normal course, the development of adaptive management plans (AMPs) will take place during the permitting process. AMPs will specify what indictors will be monitored, how often monitoring will take place, how monitoring and measurement will happen and where measurements will be taken. Indication, warning and action levels will be designated for all of the variables being monitored.

Discussion

Adaptive management plans and their associated threshold levels will be determined at permitting and will involve input from the BC Ministry of Energy, Mines and Natural Gas, the BC Ministry of Forests, Lands, and Natural Resource Operations, Fisheries and Oceans Canada, First Nations Representatives and Professional Environmental Consultants. Canadian water quality guidelines from the Canadian Council of Ministers of the Environment will play a major role in determining threshold levels. It is also anticipated that threshold levels will not only be based upon reaching a certain metal concentration but that the rate of change in the metal concentration will also be taken into account in determining thresholds. This will facilitate the prediction of timing to install further mitigation before the onset of any significant adverse effects.

Examples of some of the variables to be monitored in the Fish Lake and Upper Fish Lake watershed as well as possible threshold determination guidelines are listed below.

a) Nutrient Levels:

- Any/all threshold triggers to be determined.
- Continuous adverse trend in a nutrient level that is approaching or is at 50% of established (CCME 2013) criteria.
- Several consecutive observations at extreme (95 percentile) values, as determined by baseline study, and/or
- As the rates of change in nutrient levels are neither similar nor constant over time, seasonal triggers for each nutrient will need to be established.

b) Metal Levels:

- Continuous or instantaneous adverse trend in a dissolved metal level that is approaching or is at 50% of established criteria (CCME 2013).

- Several consecutive observations at extreme (95 percentile) values, as determined by baseline study, and/or as the rates of change in metal levels are not similar nor constant over time, seasonal triggers for each nutrient will need to be established.

c) Dissolved Oxygen:

- Continuous or instantaneous adverse trend in dissolved oxygen levels that is within 10% of minimum concentration criteria (BC Guidelines for the Protection of Aquatic Life, CCME 2013), and/or

- continuously trending (+/-) and approaching or is at a 50% change from its baseline (+/-) value.

d) pH:

- Continuous or instantaneous adverse trend in pH that is within 10% of the minimum or maximum threshold criteria (BC Guidelines for the Protection of Aquatic Life, CCME 2013)

- Several consecutive observations at extreme (95 percentile) values, as determined by baseline study

e) Temperature:

- Continuous or instantaneous adverse trend in temperature that is within 10% of established criteria (BC Guidelines for the Protection of Aquatic Life, CCME 2013)

f) Water Discharge:

- Continuous or instantaneous adverse trend in tributary discharge that is approaching or is at 50% of established criteria as set out in the EIS and MMER Compensation Plan

g) Fish Access:

- One or more active blockages on tributaries are identified

h) Pool Depth:

- Pool depth is insufficient for overwintering and/or seasonal rearing (fish stranding is observed)

i) Spawning Gravel:

- Gravel substrates are underutilized (approaching or at 50% of established MVP predicted densities)
- Poor egg-to-fry survival as measured annually (see biological measureable parameter)

j) Bank Stability:

- Regular monitoring of bank stability and fish use

k) Fish Health (parasites/diseases):

- Annual assessment of fish health (internal/external, parasites and/or diseases determines an increasing trend(s) in those parameters that is approaching or is at a 50% change from its baseline (+/-) value or established criteria

l) Fish Health (metals accumulation):

- Annual fish tissue analyses of metals accumulations determines an increasing trend(s) in one or more parameters that is approaching or is at a 50% change from its baseline (+/-) value or established criteria (CCME 2013)

m) Spawning Population:

- Annual estimates of Rainbow Trout spawning and emergent fry populations in Reach 8 and Fish Lake Tributary 1 to determine a decreasing trend in spawner abundance that is approaching a population of 7,600 spawners.

n) Invertebrates (benthic and pelagic):

- Continuous adverse trend in benthic or pelagic invertebrate populations or species diversity that is approaching or is at 50% change from its baseline (+/-) value

References

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