

1 Introduction

Zajdlik & Associates Inc was retained by the Snap Lake Environmental Monitoring Agency and M. Squires (Water Matters Consulting) was retained by the Department of Fisheries and Oceans to jointly comment on the Action Levels proposed in the AEMP Response Framework (DeBeers, 2012). General comments and recommendations (Section 2) are followed by comments and recommendations related to specific Action Levels proposed by De Beers (Section 3).

Recommended Action Levels aim firstly to preserve fish productivity and secondly to maintain biodiversity in Snap Lake. Based on Snap Lake AEMP data and drawing on ecological theory and empirical studies of other lakes, Action Levels should be considered *provisional* until each can be corroborated with a Snap Lake Food Web Model (discussed herein) based on existing information and the fish and food web studies proposed by De Beers (De Beers 2012).

2 Setting Action Levels for Snap Lake

2.1 How to Set Action Levels

Identifying critical threshold values for ecosystem components (e.g. nutrient concentrations and availability of edible algae) beyond which the lake food web may be at risk of breakdown must be lake specific. Knowledge of ecosystem components is comprised of AEMP data for 2004 to 2012. A general conceptual model of the Snap Lake food suggests how ecosystem components may be connected, as follows: nutrient inputs - production of edible algae (planktonic and benthic) - grazing by zooplankton and benthic invertebrates - growth of invertebrates and large bodied zooplankton - consumption of zooplankton and invertebrate prey by planktivorous fish - consumption of planktivores by piscivorous fish – a healthy fish community. More than a rudimentary understanding of the Snap Lake food web (i.e. vague statements regarding ‘ecological stability’ & ‘ecosystem function’) however is needed to set Action Levels for ecosystem components. De Beers acknowledges the dependence of ecological stability on food chain connections (from De Beers 2013, Point 6) and agrees there is need for greater scientific rigour in setting Action Levels for perturbations to benthic and plankton communities and water chemistry (DeBeers 2013, Points 10, 13 & 16, respectively) .

The scientific rigour required to set Action Levels can be provided by a simulation model of the Snap Lake food web. The model would mathematically connect changes in water quality (e.g. phosphorus inputs) with changes in the lake food web and make quantitative predictions about the response to plankton and fishes to changes in water chemistry (e.g. Walters et al., 1991). Based on understanding how nutrient inputs affect the availability of edible phytoplankton, and how energy fixed by primary producers is transferred up the food chain to fish, a simulation model can predict whether impacts on fish populations will be nil, positive, or negative. Indeed, there is no *a priori* reason to believe a change to an ecosystem component will have negative consequences for the lake food web. For instance, intentional addition of nutrients to salmon

nursery lakes has in some cases resulted in increased productivity of edible algae, large-bodied zooplankton and, in turn, the target fish species (e.g. Hyatt and Stockner, 1985).

Development of a simulation model of the Snap Lake food web will require investigation of trophic level (algae-grazers-planktivores-piscivores) interactions including fish diets and feeding habits, and of diet composition/consumption rates, and/or stable isotope/energy-trophic position analysis. Once developed, a simulation model of the Snap Lake food web would provide basis for setting and testing ecologically meaningful and scientifically defensible Action Levels.

2.2 Current Status of Snap Lake: Good News and Reason for Concern

First is the good news story. Some of the changes underway in Snap Lake may be helping rather than harming the fishery. Occurrences of anoxia that can stress fish by decreasing feeding habitat may be less frequent than before discharge of effluent to Snap Lake. Effluent discharge may also be warming lake waters. As long as waters do not become too warm, increases in temperature could extend the growing season and perhaps increase growth rates of plankton and fish during the open water season. In addition, effluent discharge releases phosphorus and blasting releases nitrogen to lake waters. Small additions of phosphorus accompanied by additions of nitrogen have potential to increase the supply of edible phytoplankton for zooplankton and in turn increase the availability of the zooplankton prey items consumed by fish (e.g. Hyatt and Stockner, 1985). In Snap Lake, it appears nutrient additions are favouring growth of edible as well as inedible algal species (SL AERR 2012, Figs. 3.2-15 and -16, p. 135 & 136 respectively). Although the composition of the algal community may be undergoing change as a result of changes in water chemistry, etc. the availability of grazeable algae in Snap Lake appears to have increased relative to baseline levels (see Proposed Action Level 1, below).

Next is the reason for caution though not panic. While edible phytoplankton appear to be plentiful, high quality zooplankton (e.g. daphnia) appear to be scarce in Snap Lake. Macrozooplankton prey can represent a critical link between edible phytoplankton and fish (Beauchamp et al., 2004; Brooks & Dodson, 1965; Mazumder & Edmundson, 2002). While it is indeed possible daphnia scarcity indicate a bottleneck in the transfer of energy up the food chain to fish, it is equally plausible that macrozooplankton densities are low as a result of predation (Mazumder & Edmundson, 2002), or that the AEMP sampling regime is mismatched with seasonal zooplankton dynamics and misses peak daphnia abundance (Beauchamp et al., 2004). In the event mine-related changes to Snap Lake have indeed led to decrease in the supply of good quality zooplankton (i.e. favouring small zooplankton over large cladocerans), then planktivorous fish and the piscivorous fish that feed on them could be negatively impacted (see Proposed Action Level 2, below). More frequent sampling to capture seasonal zooplankton dynamics in conjunction with fish diet studies would help assess the availability of macrozooplankton. A simulation model of the Snap Lake food web would help resolve uncertainties in the strength of the connection between edible phytoplankton and large-bodied zooplankton (see Proposed Action Level 3, below).

2.3 Action Level Recommendations

In this section two Action Levels are proposed and a recommendation is provided. Availability of edible phytoplankton and large-bodied zooplankton are the focus of Proposed Action Levels 1 and 2, respectively. The need for fish diet studies and a simulation model of Snap Lake to set and test the validity of Action Levels 1 and 2 is the focus of the recommendation. Section 3 includes Action Levels related to maintaining biodiversity, phosphorus loading limits, and water transparency, etc.

PROPOSED ACTION LEVEL 1 First, it seems imperative to maintain adequate supply of edible algae. So far, the supply of edible algae in Snap Lake appears to have increased relative to baseline (SL AERR 2012, Fig. 3.2-13, p. 126). In the event the trend is reversed and edible algal biomass (g/L) falls below say 50% of baseline values, then there may be reason for concern. Until the Snap Lake Fish Model is up and running, provisional Tiered Action Levels could be set as follows: Low 50%, Medium 60%, High 70% reduction of open water baseline edible algal biomass¹. A fifty percent reduction is arbitrary as is the proposed 80% reduction in total phytoplanktonic biomass; each needs to be verified with a simulation model of the Snap Lake food web. Based on the correspondence over time between changes in lake water chemistry and changes in the abundance and biomass of groups of edible phytoplankton it should be possible to identify the lake conditions coincident with loss of one or another species of edible phytoplankton and then look for a way to return to conditions conducive to growth of edible algae.

PROPOSED ACTION LEVEL 2 Second, it is important to determine the status of and importance to fish of a supply of macrozooplankton and benthic invertebrates, and to quantify supply versus consumption rates. Two strategies should help ascertain the status and functional importance of macrozooplankton in the lake food web, as follows: 1) monitor seasonal dynamics of large-bodied zooplankton, and 2) determine the relative importance to the Snap Lake fishery of production of macrozooplankton versus benthic invertebrates. The Fish Community Overview and in particular the stable isotope component of the study proposed by De Beers should provide information on the relative contribution to fish growth of benthic versus planktonic production. Again, a simulation model of food supplies and growth is needed to quantitatively link phytoplankton, zooplankton, benthic invertebrates, and fish. Data from the proposed fish studies will be important to model development. Until information is available on supply of macroinvertebrates and community wide consumption demand, and the Snap Lake Food Web Model is available for corroboration, provisional Tiered Action Levels for the proportion of total zooplankton biomass that is comprised of macrozooplankton could be set as follows: Low 10%, Medium 7%, High 5% of midsummer zooplankton biomass should be macrozooplankton.

PROPOSED SNAP LAKE FOOD WEB MODEL Proposal 3 ties together 1 & 2 (above) and makes the case for development of a Snap Lake Food Web Simulation Model. For example, the proposed Action Levels 1 and 2 (above) are based on a guess about the level of availability of edible algae and macrozooplankton required to maintain fish populations in Snap Lake. Guesses need to be

¹ NOTE- Action Levels for edible biomass assume a phytoplankton assemblage of roughly equal proportions of edible and inedible biomass. Thus the proposed high action level of 70% corresponds to a 35% reduction in total phytoplankton biomass.

verified or tested with a model that uses mathematical functions to link ecosystem components and fish populations. The Snap Lake Food Web Model would be able to generate scientifically defensible action levels for ecosystem components that are consistent with stakeholder valuations.

A simulation model that provides a quantitative basis for setting Action Levels beyond which the Snap Lake food web may be in peril should be a priority moving forward. A simulation model would allow predictions to be made of fish population age and structure as a function of changes in availability of edible algae and large-bodied zooplankton as a function of nutrient loading, etc. The model would provide quantitative links among nutrient inputs and phytoplankton and grazing zooplankton levels with feedback to phosphorous burial, zooplankton feeding and growth rates of planktivores (e.g. lake chub that were sampled extensively for the Snap Lake Fish Health Study) with feedback to abundance and composition of zooplankton, abundance and size composition of planktivores, and feeding and growth rate of piscivores (e.g. lake trout)². If fish diet studies reveal substantive utilization of benthic invertebrates then their production and consumption will need to be included in the model.

3 Specific Comments on the 20-Point Action Level Documents Submitted By De Beers and Recommended Revised Action Levels

i) Magnitude and Scale for Change in the Aquatic Community

One of the key EA predictions made by DeBeers is that impacts to the aquatic community will range from “low” to “negligible” (MVEIRB, 2003). “Impacts” were defined as:

- “Negligible if the water quality change would affect less than 5% of the aquatic community throughout Snap Lake or would affect more than 20% of the aquatic community in less than 1% of Snap Lake”;
- “Low if the water quality change would affect less than 10% of the aquatic community or would affect more than 10% of the aquatic community in less than 10% of Snap Lake”;
- “Moderate if the water quality change would affect more than 10% of the aquatic community in more than 10% of Snap Lake”; and,
- “High if the water quality change would affect more than 20% of the aquatic community in more than 20% of Snap Lake.”

² NOTE- the presence of northern pike in the reference study lake but not in Snap Lake may make the reference lake a poor model fishery for separating natural interannual variability from mine impacts, for instance, on prey supply and the fish food web.

Revised Action Level Recommendations: *(Table 1, below).*

Action levels for water quality proposed by DeBeers (2012) integrate both direct chemical measurement through AEMP benchmarks or site-specific water quality objectives and indirect biological measurements through aquatic toxicity tests. The action levels also incorporate spatial scales. The use of indirect biological measurements is good in that synergistic and bioavailability issues are to, the extent possible for an *ex situ* exposure, implicitly considered.

MVEIRB (2003) discusses changes in the aquatic community without being specific and spatial scales that are smaller than those proposed by DeBeers (2012). We provide recommendations that integrate the chemistry and toxicity criteria from DeBeers with the spatial scales recommended by MVEIRB (2003) and contextualized by additional productivity thresholds that are protective of fish production in Snap Lake. Thus, like the action levels proposed by DeBeers, a blend of purely aquatic measurements and ecotoxicological measurements is proposed. Note that unlike the MVEIRB (2003) recommendations, specific productivity thresholds are not defined at this time but instead should be set following development of a Snap Lake Food Web Model.

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Table 1: Proposed (De Beers and MVEIRB) and Recommended ACTION LEVELS Across a Magnitude Scale of Change (Tiered Action Level) in the Aquatic Community (Toxicological Impairment- Water Quality).

Tiered Action Level	Proposed by DeBeers (2012, Table 7.3-2).		MVEIRB (2003)	Recommendation³/Comments
Key Information	Differences between Snap Lake and reference lakes or normal range. EAR benchmarks and site-specific benchmarks.	Toxicity results for edge of mixing zone	Snap Lake normal range with spatial indices. EAR benchmarks and site-specific benchmarks.	Agree that toxicity test results comprise key information. See caveats regarding any comparisons of ecological metrics with reference lakes (point 5, below).
Negligible	Concentration not exceeding AEMP Benchmarks where they exist, or if exceeding, not due to Mine(c) AND within normal range lake-wide	No persistent sublethal toxic effects for either P. subcapitata or C. dubia in mixing zone samples.	Water quality change would affect less than 5% of the aquatic community throughout Snap Lake OR more than 20% of the aquatic community in less than 1% of Snap Lake.	Agree with DeBeers with following limitations: -“Persistent” should be defined as observed toxicity in P. subcapitata, C. dubia in 2 consecutive samples from any location OR more than 3 samples / calendar year. - Clarify definition of “not due to mine”. Any bases for comparison should be limited to Snap Lake and not regional values.
Low	Concentration greater than normal range lakewide AND concentration exceeds AEMP benchmark at the edge of the mixing zone (i.e., diffuser station) BUT Below site-specific objective at the edge of mixing zone, if one exists.	Persistent sublethal toxic effects detected for either P. subcapitata or C. dubia in mixing zone samples AND No sublethal toxic effects for Fish Early Life Stage test in mixing zone samples.	Water quality change: would affect less than 10% of the aquatic community OR would affect more than 10% of the aquatic community in less than 10% of Snap Lake,	Agree with DeBeers with following limitations: - See definition of “persistent” above. - Normal range not exceeded within area delimited by main basin midfield stations.
Medium	To be determined	To be determined	Water quality change would affect	Agree with MVEIRB (2003) spatial

³ Specific changes in ecological metrics subject to confirmation through Snap Lake Food Web Model as described below.

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Tiered Action Level	Proposed by DeBeers (2012, Table 7.3-2).		MVEIRB (2003)	Recommendation³/Comments
			more than 10% of the aquatic community in more than 10% of Snap Lake	extent using primary and secondary productivity thresholds linked to unacceptable losses in fish production through Snap Lake Food Web Model (Based on Food Web Model).
High	To be determined	To be determined	High if the water quality change would affect more than 20% of the aquatic community in more than 20% of Snap Lake	Agree with MVEIRB (2003) spatial extent using primary and secondary productivity thresholds linked to unacceptable losses in fish production through Snap Lake Food Web Model (Based on Food Web Model).
Significance Threshold	Exceeding a site-specific effects benchmark downstream of Snap Lake (Lac Capot Blanc) AND/OR Ecological stability of Snap Lake system compromised (i.e., significant biological effect linked to Mine operation) AND/OR confirmed acute lethal toxicity to fish at edge of mixing zone.			Exceeding site-specific objectives (if they exist) within Snap Lake OR unacceptable changes to fish productivity (to be defined by stakeholders) OR acute lethality in effluent for 3 consecutive sampling periods or more than 30% of samples for any combination of toxicity tests.

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Rationale:

Action levels and spatial extent of change should acknowledge MVEIRB (2003) while at the same time recognizing unanticipated changes in Snap Lake.

ii) Plankton and Benthic Macroinvertebrate Low Action Level (DeBeers, 2012, Table 7.3-2)

Revised Action Level Recommendation: *Plankton and Benthic Macroinvertebrate Low Action Level: Season-specific phytoplankton or benthic macroinvertebrate richness within Snap Lake does not decrease by more than 25% of the corresponding baseline richness.*

Rationale:

Reduced primary productivity may adversely affect biodiversity. Positive productivity–species-richness relationships prevailed among the 115 cases examined in a meta-analysis of both terrestrial and freshwater aquatic ecosystems by Cusens et al. (2012). Similarly a survey of aquatic species richness of six taxa (lacustrine phytoplankton, rotifers, cladocerans, copepods, macrophytes, and fish) in 33 lakes ranging from 10° to 74° N by Dodson et al. (2000) found the following significant quadratic response to increased annual primary productivity:

$$\text{Species Richness} = 1.08 + 1.47PP - 0.45PP^2 + 0.34A - 0.44(A \cdot PP) + 0.12(A \cdot PP^2),$$

where:

- PP is the annual phytoplankton production in $\text{g C} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$; and
- A is the lake area in hectares.

Adopting the average phytoplankton production from lakes north of 60° latitude in this study ($5.175 \text{ g C} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$; $n=4$) and assuming phytoplankton production is proportional to phytoplankton biomass, then the 80% reduction in phytoplankton biomass Action Level proposed by DeBeers corresponds with potential for 76% reduction in species richness (among the 6 groups investigated) within Snap Lake. This seems unacceptable.

DeBeers (2012, Table 7.3-2) proposes ambiguous “declines beyond the normal range” for a “Low” action level. A species richness criterion is recommended in addition to the “Low” action level in Table 7.3-2 (DeBeers, 2012) for each of plankton and benthic communities as follows:

Plankton and Benthic Macroinvertebrate Low Action Level: Season-specific phytoplankton or benthic macroinvertebrate richness within Snap Lake does not decrease by more than 25% of the corresponding baseline richness.

The 25% decrease in biodiversity for a low level effect is approximately consistent with a “critical effect size” of 2 standard deviations for benthic macroinvertebrates as recommended by Environment Canada (2012). Any ecological implication of decrease in richness will need

to be resolved with fish diet studies and the proposed Snap Lake Food Web Model. The ultimate goal is to ensure unacceptable effects as defined by stakeholders do not occur.

iii) Phytoplankton Significance Threshold: (DeBeers, 2012, Table 7.3-2)

Revised Significance Threshold Recommendation: *The phytoplankton biomass Significance Threshold should be set to much lower than 80% reduction, say a provisional level of 20% decrease until such time as a Snap Lake Food Web Model can be used to predict what reduction in phytoplanktonic biomass will not cause unacceptable changes in fish production.*

Rationale:

Downing et al. (1990) examined relationships between lake characteristics and fish productivity developed over 40 years for 20 lakes of varying trophic status and over a wide geographic region. The strongest predictor of fish production was primary productivity and is described by:

$$\log_{10}(\text{FP}) = 0.600 + 0.575 \log_{10}(\text{PP}) ,$$

where:

- PP is the annual phytoplankton production in $\text{g C}\cdot\text{m}^{-2}\cdot\text{yr}^{-1}$; and
- FP is the annual fish production in $\text{kg}\cdot\text{ha}^{-1}\cdot\text{yr}^{-1}$.

Assuming that phytoplankton production is proportional to phytoplankton biomass in Snap Lake, then the 80% reduction in phytoplankton biomass Action Level proposed by DeBeers could mean 80% reduction in fish production in the lake. It seems doubtful this level of reduction in fish production would be acceptable to stakeholders.

The Dodson et al. (1990) study also examined the effects of pelagic primary production on diversity and fish production. In Snap Lake, it is possible that benthic primary production could offset any massive losses in phytoplankton primary production (Raution and Vincent, 2006; Vander Zanden et al., 2006; and Northington et al., 2010). Moreover, high benthic production in oligotrophic lakes may be supported by benthic algal production plus detrital / allochthonous C (Hershey et al., 2006 and Solomon et al., 2008) and possibly, methanotrophy (Hershey et al., 2006) of which we know nothing about in Snap Lake. At this point it is not clear that such benthic pathways exist in Snap Lake or that if substantive reduction in phytoplankton production could be offset by fish switching to benthic from pelagic food resources (e.g. Vadeboncoeur et al., 2003). Finally any decreases in phytoplankton biomass due to toxicity are likely to correspond with concomitant losses in benthic primary producer biomass.

De Beers is proposing a study of littoral zone productivity to address the contribution of benthic production to overall primary production in Snap Lake. An 80% reduction in phytoplankton biomass should not be considered acceptable until the relative contribution of benthic production to fish production is estimated and only if evidence can show that

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proposed reduction in phytoplankton biomass would not reduce fish production to levels unacceptable to stakeholders.

This significance threshold for phytoplankton biomass decrease should be set to a much lower provisional level, say 20% until such time as a Snap Lake Food Web Model can be used to predict what reduction in phytoplanktonic biomass will not cause unacceptable changes in fish production.

iv) Water Quality as defined by nutrients and chlorophyll *a*: (DeBeers 2012, Table 7.3-3)

Revised Action Level Recommendation: *i) Nutrient chemistry Action Levels should be based on phosphorus inputs in conjunction with mean water depth and lake flushing rate rather than on phosphorus and chlorophyll concentrations in lake water. Until information on phosphorus loading (natural plus effluent), etc. and the Food Web Model is available, Action Levels total phosphorous (TP) can be set as follows: Low TP>25 µg/L; Medium 30 µg/L; High 35 ug/L. ii) Chlorophyll a and suspended sediment concentrations need to be monitored in conjunction with measurements of water transparency measured as the coefficient of light attenuation. Until information on light attenuation, etc. is available Action Levels should be set for water transparency based on percent reduction relative to baseline depth of the euphotic zone and extent of the littoral zone: Low 20%, Medium 30%, High 40%.*

Rationale:

- i) Phosphorus input (not concentration) drives algal productivity. Although there is a need to monitor both phosphorus input and concentration, algal productivity is a function of inputs and fate of phosphorus (export, burial). Further, because a large proportion of phosphorus is contained in plankton biomass during the growing season, predictions about open water phytoplankton production should be based on phosphorus concentration at lake ice out (Dillon and Rigler 1974). Moreover, phosphorus availability at ice out can be predicted from phosphorous loading (natural plus effluent), mean water depth, and water residence time (Vollenweider 1973; Michalski et al. 1973). The Snap Lake Food Web Model (Proposal 3, above) would incorporate phosphorus loading as well as export and burial and provide a basis for setting an Action Level for annual phosphorus inputs that should avoid reaching a level of eutrophication that would harm the lake food web and fish populations. Until Action Levels for total phosphorus (TP) during open water (TP includes what is contained in plankton) can be based on the general relation between TP and proportion of edible and inedible phytoplankton (Watson et al. 1992), we recommend the following provisional action levels: Low TP>25 µg/L; Medium 30 µg/L; High 35 ug/L.
- ii) There is a need to monitor chlorophyll concentration and suspended sediment content as both are important controls on water transparency and in turn, the depth of the euphotic zone (affects phytoplankton primary productivity) and extent of the littoral zone (affects benthic primary productivity). Until information on light attenuation, etc. is available Action Levels should be set for water transparency based on percent change in depth of the euphotic zone and extent of the littoral zone: Low 20%, Medium 30%, High 40%.

- iii) Key Information used to assess mine impacts is based on differences between Snap Lake and reference lakes representing 'normal range' (DeBeers, 2012, Table 7.3-2). (See below for concerns regarding this comparison).

Revised Action Level Recommendation: *The reference system NE Lake and Snap Lake differ in important ways. Among other attributes, there are differences in trophic status and food web structure with implications for phytoplankton and zooplankton assemblages. As a result, it is recommended that potential impacts of the mine on ecosystem components and the Snap Lake food web rely primarily on Snap Lake baseline data and secondarily on comparisons with NE Lake.*

Rationale:

The presence of northern pike (jackfish) in the reference lake but not in Snap Lake may mean the reference is a poor model for separating natural interannual variability from mine impacts. For instance, a lake with piscivorous pike (NE reference lake) may have relatively low abundance of planktivorous fishes and phytoplankton, and relatively high abundance of large zooplankton. A lake without a strong piscivore population such as pike (Snap Lake) may have relatively high abundance of planktivores and phytoplankton, and relatively low abundance of large zooplankton. In lakes with pike, high zooplankton grazing pressure could potentially deplete the standing crop of edible algae and thereby alter phytoplankton community composition. In non pike lakes, high planktivore grazing pressure could deplete the pool of large-bodied zooplankton and thereby alter community composition of zooplankton with implications for phytoplankton assemblages.

4 A General Path toward Action Levels that will Protect Fish Productivity in Snap Lake

In summary, recommended steps towards Action Levels that will protect Snap Lake's fish populations are outlined below:

- Consult with stakeholders to determine what change in fish production is acceptable.
- Assess the relationship between primary production and phytoplankton biomass in Snap Lake, and between light attenuation and depth of the euphotic zone and extent of the littoral zone.
- Conduct a full literature review of the relationship between primary production (both phytoplanktonic and benthic) and fish production, particularly for Arctic lakes (e.g. Ramlal et al., 1994; Hecky & Hesslein, 1995; Vadeboncouer, et al., 2002 and Squires et al., 2009).
- Create a Snap Lake Food Web Model to set scientifically defensible Action Levels that are linked to avoidance of unacceptable changes in fish production. The Food Web Model should quantitatively link ecosystem components as follows: nutrient inputs and

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phytoplankton and grazing zooplankton levels with feedback to phosphorous burial; zooplankton feeding and growth rates of planktivores with feedback to abundance and composition of zooplankton; abundance and size composition of planktivores; feeding and growth rate of piscivores; and if fish diet studies reveal substantive utilization of benthic invertebrates then their production and consumption will need to be included in the model.

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