APPENDIX 8.V

EMPIRICAL DISSOLVED OXYGEN MODELLING

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8.V.1 INTRODUCTION

Kennady Lake is classified as an oligotrophic lake based on total phosphorus trigger ranges for Canadian lakes and rivers in Environment Canada (2004) and CCME (2004). Baseline total phosphorus concentrations range from <0.001 to 0.010 mg/L during under-ice conditions and <0.001 to 0.006 mg/L during open water conditions (see Section 8.3.6). During winter, when a lake is covered by ice and isolated from inflows and the atmosphere, natural mixing and aeration processes effectively cease. Under these conditions, a net dissolved oxygen reduction occurs within the water column, which progresses over the course of winter. The rate of dissolved oxygen consumption in ice-covered lakes depends on a series of interconnected physical and biochemical factors, including temperature, vital functions of various organisms (especially the benthic community), organic matter concentration, and dissolved oxygen concentrations in the near-bottom layers of the water column (Mathias and Barica 1980; Golosov et al. 2007).

Increases in total phosphorus concentration in Kennady Lake during post-closure could potentially lead to increased primary productivity, and hence higher concentrations of organic carbon. During ice-covered conditions, the increased availability of organic material would increase winter dissolved oxygen demand, which would increase the rate of oxygen depletion, and therefore result in reduced dissolved oxygen concentration in the water column. Winter dissolved oxygen demand under baseline conditions, and for predicted long-term steady state phosphorus concentrations, in Kennady Lake were evaluated using three empirical approaches to assess the potential effects to fish and fish habitat (i.e., the availability of dissolved oxygen within Kennady Lake to support fish after closure; see Section 8.10). These approaches are described in the following section.

8.V.2 METHODS

An upper-bound estimate of dissolved oxygen demand during under-ice conditions was calculated based on measured baseline dissolved oxygen concentrations in Kennady Lake (Section 8.3.6) and three empirical relationships available in published literature: Approach 1 is based on total phosphorus concentration and average lake morphometry; Approach 2 uses annual rate of primary productivity based on total phosphorus concentrations; and Approach 3 uses sediment oxygen demand based on lake trophic status.

The three approaches described below do not provide depth-specific oxygen depletion rates, but rather estimate a general lake winter oxygen depletion rate (WODR). Based on the depth delineation established from baseline data in Kennady Lake during under-ice conditions (i.e., top = under ice to 6 m, middle = 6 to 12 m, and bottom = >12 m), WODRs were estimated at these specific depth zones for each of the three approaches. These depths were selected using three equally distributed depth zones (i.e., the maximum depth in Kennady Lake is 18 m).

The estimation of WODRs did not include the open Hearne and Tuzo pits, but have focussed on the remaining areas of Kennady Lake. The open pits will have a deeper epilimnetic zone, that will extend to deeper regions that other areas in Kennady Lake due to their greater depths (>100 m). The volume of water within the open pits that may be associated with the deeper epilimnetic zone (e.g., from 5 to 40 m deep) would represent 16 Mm^3, or approximately 50% of the volume in the other areas of Kennady Lake. As the mass of oxygen that would be present in this volume over winter has not been included in the estimation, the projected end-of-winter dissolved oxygen concentrations for each approach are based on some conservatism.

8.V.2.1 APPROACH 1

This approach provides a direct method to determine the winter oxygen depletion rate (WODR) based specifically on summer phosphorus concentrations in the euphotic zone and average lake depth (Babin and Prepas 1985):

WODR ($g\ O_2/m^2$/day) = $-0.101 + 0.00247 \times [TP] + 0.0134 \times \dot{Z}$, ($r = 0.90$);

Where,

TP = summer total phosphorus concentration (mg/m^2) in the euphotic zone, and

$\dot{Z}$ = average water depth (m).

This empirical model was derived from data collected from 33 Canadian lakes in winter that ranged in surface area from 0.08 km^2 to 4.4 km^2, average depth from 1.5 m to 27.2 m, and TP from 24 mg/m^2 to 222 mg/m^2. Winter conditions had a nominal under-ice period of 112 days.

8.V.2.2 APPROACH 2

This approach is based on the calculation of annual primary productivity using an annual average total phosphorus concentration, which is converted to a theoretical oxygen demand.

Step 1:

The long-term steady state total phosphorus concentration was used to calculate an annual primary productivity according to Vollenweider (1979) (also cited in Wetzel 2001):

$$C = 7 \times \left[\frac{\left\{ \frac{[P]_i}{\left(1 + \sqrt{\tau_w}\right)} \right\}^{0.76}}{0.3 + 0.011 \times \left\{ \frac{[P]_i}{\left(1 + \sqrt{\tau_w}\right)} \right\}^{0.76}} \right]$$

Where,

C = annual rate of primary productivity (g C/m^2/yr), where C is carbon,

$[P]_i$ = average concentration of total phosphorus (mg/m^3), and

τ_w = average residence time of lake (y).

Step 2:

The calculated annual rate of primary productivity was then converted to a theoretical oxygen demand using the following equation:

$$C + O_2 \rightarrow CO_2$$

Considering the molar mass of carbon and oxygen is 12 and 32 grams per mole (g/mol), respectively, 32 grams (g) oxygen is required to convert 12 g of organic carbon into the inorganic form. For this estimation, it was assumed that 50% of the autotrophic carbon would be assimilated in the winter, which is conservative, as the rate of organic carbon decomposition in summer is reported to be 100% higher than in winter (Kelly et al. 1984). The lower assimilation rates in winter are attributed to very low winter temperatures and accordingly low rates of respiration (decomposition).

8.V.2.3 APPROACH 3

This approach utilizes sediment oxygen demand to determine WODR based on trophic status; total phosphorus concentrations are not specified in the relationship, but are inferred from the trophic status. Mathias and Barica (1980) suggested sediment oxygen demand, and not water column oxygen consumption, contributes more substantially to differences in dissolved oxygen concentration between productive and less productive lakes. They developed the following two empirical relationships:

WODR (g O_2/m^3/day) = 0.226x + 0.010 for eutrophic lakes (r = 0.72), and

WODR (g O_2/m^3/day) = 0.075x + 0.012 for oligotrophic lakes (r = 0.78);

Where,

x = ratio of surface area of sediment/lake volume (m^2/m^3).

This pair of empirical relationships for Approach 3 was derived from data from Canadian lakes that included 23 prairie lakes, five arctic lakes, 26 Experimental Lake Area (ELA) lakes (north-western Ontario), and 16 Ontario lakes, with chlorophyll *a* concentrations ranging from 0.1 mg/m^3 to 300 mg/m^3. The estimations for Kennady Lake were achieved through applying these relationships at half metre depth intervals in Kennady Lake, estimating the lake volume for each depth interval, and where appropriate, using the relative sediment surface area.

8.V.3 EFFECTS OF PROJECT ACTIVITIES ON DISSOLVED OXYGEN IN KENNADY LAKE AND AREA 8

Upper-bound estimates of oxygen demand during under-ice conditions were calculated based on empirical relationships described in Section 8.V.2. These approaches are expected to provide a range of WODRs representative of baseline conditions, and using a projected phosphorus concentration of 0.018 mg/L.

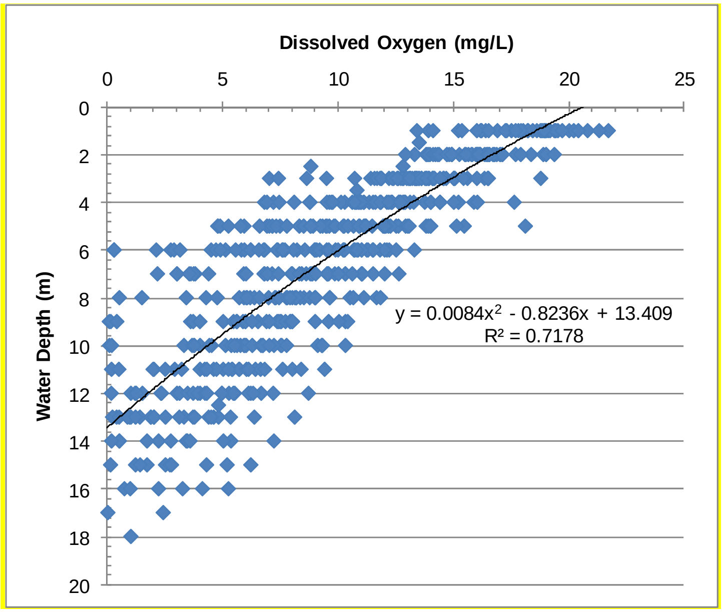
8.V.3.1 BASELINE DISSOLVED OXYGEN DEMAND

Baseline winter dissolved oxygen data for Kennady Lake are limited to periods in later winter (i.e., January to May, 1998 to 2004; see Section 8.3.6). The range of dissolved oxygen profile data for stations in Kennady Lake during the late under-ice period are illustrated in Figure 8.V-1. Dissolved oxygen concentrations through the water column under-ice are highly variable, with instances of anoxia being prevalent below 6 m in some areas of Kennady Lake. Thirty percent of the measured baseline dissolved oxygen concentrations during late winter conditions (March, April and May) were below the CCME guideline level (6.5 mg/L) for cold water biota.

As the relationship between dissolved oxygen concentration and depth was not linear, three water column zones were identified to estimate the baseline winter oxygen depletion rate (WODR) in Kennady Lake: surface (below ice to 6 m), middle (6 to 12 m), and bottom (greater than 13 m). As higher oxygen demands occur at greater depths due to the higher influence of sediment oxygen demand, the segregation of depth zones is appropriate for an estimation of effects from phosphorus enrichment. For the surface depth zone, a nominal 1 m surface water depth was excluded from the calculation as the maximum measured thickness of ice in Kennady Lake under baseline conditions was 2 m.

The average under-ice baseline dissolved oxygen concentration determined at the end of the winter season for each selected depth zone was 11.6, 4.5, and 1.4 mg/L in the surface, middle, and bottom zones of the lake, respectively. Average measured dissolved oxygen profiles in April for surface and middle depth zones were 12.5 and 4.7 mg/L, respectively (in April, no baseline data were available below 12 m); these values are similar to the estimated end-of-winter concentrations.

Figure 8.V-1 Baseline Winter Dissolved Oxygen Data for Kennady Lake, 1998 to 2004



As early winter (September to October) under-ice dissolved oxygen profile data were not available, dissolved oxygen concentrations at initial freeze-up were assumed to be 15 mg/L in the surface depth zone, 12 mg/L in the mid-depth zone, and 10 mg/L in the bottom zone. These concentrations were based on the projected winter temperature profile likely present at the start of winter, i.e., ranging from near 0°C in the surface zone, to 4°C at the bottom of the water column. The dissolved oxygen concentrations for each depth zone at these temperatures represent approximately 100% saturation in the surface zone, and approximately 90% and 80% saturation in the middle and bottom zones, respectively. Considering that under baseline conditions, occurrences of more than 100% oxygen saturation have been reported in the surface zone just before freeze up, and a well-mixed water column can prevail at the beginning of winter, the assumed initial oxygen levels represent conservative dissolved oxygen conditions through the water column at the start of the under-ice period.

The earliest measured dissolved oxygen concentrations for baseline winter conditions averaged over the specific depth zones in January were 14.2, 9.5, and 4.6 mg/L. These data correspond reasonably well to the estimated winter starting estimates for the surface and middle zones. The lower dissolved oxygen concentration in the bottom zone reflects the higher oxygen demand and lower volumes associated with the deeper zone.

The total dissolved oxygen mass depleted in each depth zone was estimated by subtracting the final dissolved oxygen mass from the initial dissolved oxygen mass, based on an under-ice period of 240 days (Table 8.V-1).

Table 8.V-1 Estimated Winter Oxygen Depletion Rates at Different Depth Zones of Kennady Lake under Baseline Conditions

Layer	Water Volume	Dissolved Oxygen Level and Mass at Start of Ice Cover		Dissolved Oxygen Level and Mass at End of Ice Cover		Winter Oxygen Depletion Rate		
	m^3	mg/L	g/total vol	mg/L	g/total vol	g/total vol/240 d	mg/L/d	%
Top	23,755,264	15	356,328,960	11.6	274,373,299	81,955,661	0.0144	18
Middle	6,518,846	12	78,226,152	4. 5	29,008,865	49,217,287	0.0315	38
Bottom	100,063	10	1,000,630	1.4	136,086	864,544	0.036	44
Water Column Average							0.0273	100

m^3 = cubic metre; mg/L = milligrams per litre; g/total vol = grams per total volume in depth zone, g/m^3/240 d = grams per cubic metre per 240 days; mg/L/d = milligrams per litre per day; % = percent

8.V.3.2 ESTIMATION OF DISSOLVED OXYGEN DEMAND UNDER PROJECTED LONG-TERM STEADY STATE TOTAL PHOSPHORUS CONCENTRATIONS

Approach 1

The WODR model of Babin and Prepas (1985) is based on lake areal units. Conversions to volumetric units were made using total surface area and total volume of Kennady Lake (excluding a nominal surface ice depth of 1 m). The model estimated a dissolved oxygen demand of 0.175 g/m^2/d, which is equivalent to a volumetric demand of 0.036 mg/L/d (Table 8.V-2).

Table 8.V-2 Estimated Winter Oxygen Depletion Rate for a Total Phosphorus Concentration of 0.018 mg/L in Kennady Lake

Variable	Units	Kennady Lake
Total Phosphorus	mg/L	0.018
	mg/m^2	87.93
Volume	m^3	30,374,173
Area	m^2	6,218,177
Average depth	m	4.88
Dissolved oxygen demand	g/m^2/d	0.175
	mg/L/d	0.036

mg/m^2 = milligrams per square metre; m^3 = cubic metre; m^2 = square metre; m = metre; g/m^2/d = grams per square metre per day; mg/L/d = milligrams per litre per day.

Approach 2

The Vollenweider (1979) model estimated an areal primary productivity of 63.18 g C/m^2/y based on 0.018 mg/L phosphorus in Kennady Lake. On the basis that 50% of the annual carbon production would be metabolized during the winter period (Kelly et al. 1984), a corresponding WODR of 0.231 g/m^2/d or 0.0472 mg/L/d would result (Table 8.V-3). A 50% carbon metabolism is considered conservative, as winter water temperatures in Kennady Lake are cold (typically 0 to 4°C), which limits the rate at which biological processes occur. In addition, much of the organic carbon is likely to settle to the sediments and exert an oxygen demand through slower, diffusive processes. This mechanism has been observed in mesotrophic lakes, where dissolved oxygen levels remained near saturation at the surface, but declined to zero at the sediment-water interface (Agbeti and Smol 1995).

Table 8.V-3 Estimated Dissolved Oxygen Requirement for a Total Phosphorus Concentration of 0.018 mg/L in Kennady Lake

Constituent	Units	Kennady Lake
Total Phosphorus	mg/L	0.018
	mg/m^3	18
Volume	m^3	30,374,173
Area	m^2	6,218,177
Flow rate	m^3/y	2,912,287
Residence time	Y	10
Molar mass of carbon	g/mole	12.01
Molar mass of oxygen	g/mole	32.00
Primary productivity	g C/m^2/y	63.18
	moles C/lake/y	16,355,213
Oxygen demand	g/m^2/d	0.231
	mg/L/d	0.0472

mg/m^3 = milligrams per cubic metre; m^3 = cubic metre; m^2 = square metre; m^3/y = cubic metre per year; y = year; g/mol = grams per mol; g C/m^2/y = grams of carbon per square metre per year; mol C/lake/y = moles of carbon per lake per year; g/m^2/d = grams per square metre per day; mg/L/d = milligrams per litre per day.

Approach 3

Using the Mathias and Barica (1980) model, the average volumetric WODRs for Kennady Lake using the oligotrophic and eutrophic formulae were 0.0346 and 0.0781 mg/L/d, respectively. The predicted value for Kennady Lake based on oligotrophic condition was slightly higher than the averaged baseline WODR calculated for Kennady Lake (0.0273 mg/L/d); however, the baseline WODR for the deeper zone (0.036 mg/L/d) in close proximity to the lake bed sediment was similar. This approach is very much driven by sediment oxygen demand processes, and is expected to provide the uppermost bound of WODR among the three approaches.

Kennady Lake is expected to be a mesotrophic lake in the long term. As a relationship for mesotrophic lakes was not determined by Mathias and Barica

(1980), a mid-range WODR from between the two trophic conditions was assigned (i.e., 0.275 g/m^2/d or 0.0563 mg/L/d) by averaging the values representing oligotrophic and eutrophic conditions (Table 8.V-4). Taking the mid-range between the two trophic conditions assumes a linear relationship between oligotrophic and mesotrophic conditions, and the value does fall within the range of WODRs (0.25 to 0.40 g/m^2/d) that are regarded as mesotrophic (Nürnberg 1996).

Table 8.V-4 Estimated Winter Oxygen Depletion Rate in Kennady Lake based on Different Trophic Levels

Trophic State	Volume	Lake Area	Winter Oxygen Depletion Rate	
	m^3	m^2	g/m^2/d	mg/L/d
Oligotrophic lake	30,374,173	6,218,177	0.1690	0.0346
Eutrophic lake	30,374,173	6,218,177	0.3815	0.0781
Kennady Lake (average)	30,374,173	6,218,177	0.2753	0.0563

m^3 = cubic metre; m^2 = square metre; g/m^2/d = grams per square metre per day; mg/L/d = milligrams per litre per day.

The range of WODRs for Kennady Lake using the different approaches (0.175 to 0.275 g/m^2/d; Tables 8.V-2 to 8.V-4) is within the range of published data, as shown by the following examples:

- 0.243 to 0.848 g/m^2/d for 11 ice-covered Alberta lakes in Babin and Prepas (1985);
- 0.12 to 0.38 g/m^2/d for three arctic lakes in White et al. (2008);
- 0.04 to 0.25 g/m^2/d for 11 north-western lakes in Ontario in Schindler (1971); and
- 0.1 to 0.2 g/m^2/d for lakes above 75° N in Welch (1974).

The three approaches provide a broad range of potential WODRs for Kennady Lake.

8.V.3.3 WINTER OXYGEN DEPLETION RATES IN DIFFERENT DEPTH ZONES OF KENNADY LAKE

Based on the ratio of WODR for each depth zone determined from the measured baseline winter dissolved oxygen water column profile data, volumetric WODR estimates were calculated for the three depth zones for each approach (Table 8.V-5). This information can be used to estimate changes to WODR and resultant projections of dissolved oxygen in each depth zone with higher phosphorus concentrations.

Table 8.V-5 Summary of Winter Oxygen Depletion Rates in Different Depth Zones of Kennady Lake using Baseline Data and Empirical Model Approaches

Pre/Post Closure Condition	Winter Oxygen Depletion Rate (mg/L/d)			
	Top	Middle	Bottom	Whole Lake
Baseline Condition	0.0144	0.0315	0.036	0.0273
Long-term Steady State Condition				
Approach 1	0.0194	0.0410	0.0475	0.0360
Approach 2	0.0255	0.0538	0.0623	0.0472
Approach 3	0.0304	0.0642	0.0743	0.0563

mg/L/d = milligrams per litre per day; % = percent.

8.V.3.4 ESTIMATION OF WINTER DISSOLVED OXYGEN BALANCE UNDER A PROJECTED LONG-TERM STEADY STATE TOTAL PHOSPHORUS CONCENTRATION OF 0.018 MG/L IN KENNADY LAKE

The dissolved oxygen balance for the last day of the winter period using the estimated WODRs was estimated based on the following assumptions:

- a 240-day winter period of ice-covered conditions;
- dissolved oxygen concentrations of 15, 12, and 10 mg/L at the top, middle, and bottom zones at the beginning of winter; and
- no autotrophic dissolved oxygen production or vertical mixing during the ice-covered winter period.

The estimated average dissolved oxygen concentration for each of the depth zones in Kennady Lake during post-closure is listed in Table 8.V-6 and compared to average baseline conditions. The results indicate that dissolved oxygen concentrations in the surface zone of the water column over the winter period will likely remain above the guideline concentration of 6.5 mg/L for cold water fish for the range of estimated WODRs. The dissolved oxygen levels at the mid-depth and bottom depth zones are projected to fall below the guideline concentration.

Table 8.V-6 Estimated Dissolved Oxygen Balance at Different Depth Zones in Kennady Lake at the End of Winter

	Depth Volume	Winter Start Dissolved Oxygen		Winter Oxygen Depletion Rate		Winter End Dissolved Oxygen	
	m^3	mg/L	g/total vol	mg/L/d	g/total vol/240 d	g/total vol	mg/L
Baseline Condition							
Top	23,755,264	15	356,328,960	0.0144	81,955,661	274,373,299	11.55
Middle	6,518,846	12	78,226,158	0.0315	49,217,287	29,008,865	4.4 5
Bottom	100,063	10	1,000,630	0.0360	864,544	136,086	1.36
Post-closure Condition							
Approach 1							
Top	23,755,264	15	356,328,960	0.0194	110,604,509	245,724,451	10.34
Middle	6,518,846	12	78,226,158	0.0410	64,145,445	14,080,707	2.16
Bottom	100,063	10	1,000,630	0.0475	1,140,718	-140,088	0 [(a)]
Approach 2							
Top	23,755,264	15	356,328,960	0.0255	145,382,216	210,946,744	8.88
Middle	6,518,846	12	78,226,158	0.0538	84,171,340	-5,945,188	0 [(a)]
Bottom	100,063	10	1,000,630	0.0623	1,496,142	-495,512	0 [(a)]
Approach 3							
Top	23,755,264	15	356,328,960	0.0304	173,318,406	183,010,554	7.70
Middle	6,518,846	12	78,226,158	0.0642	100,442,379	-22,216,227	0 [(a)]
Bottom	100,063	10	1,000,630	0.0743	1,784,323	-783,693	0 [(a)]

[(a)] the calculated dissolved oxygen is negative, but represents 0 mg/L. The negative value is used to extrapolate to the period under-ice that oxygen depletion rates resulted in 0 mg/L.

m^3 = cubic metre; g/m^3 = grams per cubic metre; mg/L/d = milligrams per litre per day; $g/m^3/240$ d = grams per cubic metre per 240 days; mg/L = milligrams per litre.

Under the modelled conditions, anoxic conditions are projected in the bottom depth under Approach 1, and middle and bottom depths under Approaches 2 and 3 (i.e., negative dissolved concentrations). These conditions are estimated to develop towards the end of the winter period as follows:

- during the last 24 days of the winter period in the bottom zone under Approach 1;
- during the last 17 and 79 days in the middle and bottom zones, respectively, under Approach 2; and
- during the last 53 and 105 days at the middle and bottom zones, respectively, under Approach 3.

For each of the three approaches and assuming saturated dissolved oxygen conditions at the start of winter, the middle and deep depth zones, which represent up to 22% of the lake volume, may become anoxic at the end of the winter; this would indicate the potential for this volume of the lake to be unsuitable for most aquatic life at the end of winter.

The areas of the lake that would be more prone to effects from higher WODRs would likely include the shallow areas of the lake where sediment oxygen demand may be high, and the middle and deeper zones of the deeper basins. However, the presence of the two large pits in Kennady Lake after closure was not included in the above estimates; these pits are expected to provide additional volumes of oxygenated water within the lake. These open pits will be deep (greater than 100 m) and possess a larger epiliminetic zone compared to the rest of Kennady Lake. This zone will be subject to the lower range of WODR than the deeper zones within the rest of the lake (i.e., there will be a negligible sediment oxygen demand). The volume of oxygenated water in the surface 40 m of the Hearne and Tuzo pits, accounting for the average depth of Kennady Lake (5 m), represents an additional 50% of the Kennady Lake volume (i.e., approximately 16 Mm^3 between 5 and 40 m depth). A large proportion of this volume of oxygenated water is expected to provide sufficient overwintering habitat for fish and refugia habitat during periods with low dissolved oxygen levels in late winter.

WODRs could potentially exceed the range outlined for the various depth zones by the three approaches. Higher WODRs would result in a larger volume of Kennady Lake that could be unsuitable to aquatic life at the end of winter. Using the upper WODR level from Approach 3 to Kennady Lake (0.0781 mg/L/d), the resultant surface depth zone dissolved oxygen concentration at the end of winter may approach 4.9 mg/L, which would mean that conditions throughout Kennady Lake would be limiting for cold-water fish species. However, this upper WODR level is conservative, because it represents a eutrophic condition in the Mathias and Barica (1980) model (i.e., total phosphorus concentrations above 0.035 mg/L).

8.V.3.5 SUMMARY

The above-noted estimates of WODR, as well as estimated dissolved oxygen concentrations, provide an indication of the range of end of winter dissolved oxygen concentrations within Kennady Lake based on the projected long-term steady state phosphorus concentration of 0.018 mg/L. The estimates were based on published empirical models for Canadian lakes, which were adjusted accordingly to measured baseline dissolved oxygen data from Kennady Lake.

For the broad range of assessment derived from the three empirical approaches, WODRs were estimated to be 32 to 106% higher during post-closure compared to baseline conditions. These increased oxygen demands are expected to affect 22% of the water volume in Kennady Lake (i.e., depths below 6 m), excluding the open Hearne and Tuzo pit volumes.

In baseline and post-closure conditions, the surface zone of Kennady Lake (i.e., under ice to 6 m) is expected to maintain sufficient dissolved oxygen concentrations to support cold-water aquatic life (greater than 6.5 mg/L). Exceptions within the surface zone would include shallow littoral zones possessing fine organic sediment, which would be subject to higher dissolved oxygen demands than shallow littoral zones possessing cobble substrate.

The open Hearne and Tuzo pits within Kennady Lake are expected to provide additional overwintering refugia by retaining dissolved oxygen concentrations at levels sufficient to maintain overwintering habitat for fish. The pits are expected to have a much deeper epilimnetic zone compared to other regions of Kennady Lake, which is associated with their greater depths (>100 m). During winters when dissolved oxygen concentrations at freeze-up are lower than average, and/or higher WODRs occur than expected within the lake, the pits would provide additional overwintering habitat for fish species that are less tolerant of low dissolved oxygen levels.

Under open-water conditions, Kennady Lake is expected to remain well mixed. In most of Kennady Lake, stratification is not expected in summer due to wind-driven circulation, and dissolved oxygen concentrations are likely to be generally uniform throughout the water column in Areas 3 to 8, ranging from 9 to 16.5 mg/L (mirroring current conditions – see Section 8.3.6), which will extend into the deeper pit depths.

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