



Final

Swan Lake Management Options

Literature Review of Management Options
and Effects of Increased Oxygenation in
Swan Lake

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NATURAL RESOURCE SOLUTIONS INC.

Aquatic, Terrestrial and Wetland Biologists

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Literature Review of Management Options and Effects of Increased Oxygenation in Swan Lake

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1.0 Purpose and Objectives

Natural Resource Solutions Inc. (NRSI) was retained by the Friends of Swan Lake Park to complete a literature review examining the potential benefits of increased oxygenation on surface water quality and overall ecological conditions within Swan Lake. The review also evaluates available methods to enhance oxygenation, along with their associated impacts, feasibility, and applicability to the lakes specific conditions. Dissolved oxygen concentrations have been identified as a key limiting factor in preliminary water quality analysis. Accordingly, the objective of this review is to provide the Friends of Swan Lake Park with a concise, evidence-based summary of the potential ecological and water quality improvements associated with increased oxygenation, to support the development of further rehabilitation and remediation strategies for Swan Lake.

1.1 Background and Scope

Swan Lake is a manmade waterbody located within the City of Markham. The lake was historically operated as a gravel quarry until the late 1970s, after which it served as a local landfill until its naturalization in the 1990s. Although Swan Lake has no natural surface water inflows or outflows, it was integrated into the municipal stormwater management system between the 1990s and early 2000s. Since that time, it has functioned as an ad hoc stormwater management facility, receiving surface water runoff from the surrounding residential developments.

Currently Swan Lake exists as a shallow, highly eutrophic lake characterized by the recurrent cyanobacterial blooms and persistently poor water quality conditions, with an average depth of approximately 1.65m. Ongoing surface water quality monitoring by the City of Markham has documented minor improvements in recent years; however, dissolved oxygen concentrations remain low, and overall aquatic habitat conditions continue to be degraded. Reduced dissolved oxygen concentrations are common in shallow freshwater pond and lake habitats, and are often associated with enhanced eutrophication, organic matter accumulation and altered nutrient cycling processes.

The scope of this literature review includes the following:

- A review of relevant scientific literature and case studies examining the ecological, chemical, and physical effects of increased oxygenation in shallow lake systems.

- A summary of management strategies and engineered interventions designed to increase dissolved oxygen concentrations, including their short and long-term implications for system function, sediment chemistry, biological communities and overall ecosystem resilience.

2.0 Literature Review Methods

As part of NRSI's review, a range of peer-reviewed journal articles, government publications, technical manuals, and documented case studies were examined to assess the potential effects of increased oxygenation on shallow surface waterbodies. The literature search emphasized material addressing topics such as 'lake oxygenation,' 'hypolimnetic oxygenation,' 'aeration,' 'oxygenation effects,' 'eutrophication management,' and 'shallow lake response.'

Priority was given to recent publications and studies conducted under comparable surface water conditions and climatic conditions. Foundational and topic-specific works were also included where necessary to provide context and support broader interpretation. The review incorporated literature addressing both Oxygenation techniques and documented ecological outcomes to ensure a comprehensive understanding of system responses to enhanced oxygenation.

3.0 Effects of Increased Oxygenation on Shallow Surface Water Bodies

Dissolved oxygen (DO) is a Fundamental parameter influencing both the chemical and biological processes that support a healthy aquatic ecosystem.. Actively increasing dissolved oxygen concentrations, commonly known as oxygenation, can have a wide range of chemical and biological effects, many of which can be beneficial to the stability and resilience of a surface water body.

Enhanced oxygenation can improve overall water quality, promote aerobic biological activity, and support the recovery of aquatic ecosystems experiencing eutrophic or hypoxic conditions. The specific effects of increased oxygenation are described below in the following sections, with emphasis on potential implications for improving existing water conditions within Swan Lake.

3.1 Effects on Surface Water Quality

Increases in surface water Dissolved Oxygen (DO) concentrations are closely associated with measurable improvements in overall water quality. Elevated DO levels have been directly linked to reducing the rate of nutrient release from nutrient-rich sediment, particularly compounds of nitrogen, phosphorus, and certain heavy metals (Andersen et al. 2017, Borman et al. 2017, Preece et al. 2019, Shaw and Prepas 1990). This reduction in internal nutrient loading helps to mitigate the effects of organic nutrient contamination by chemically inhibiting chemical release or nutrient flux from sediments and promoting aerobic bacterial activity, which lead to an increase in the rate of organic nutrient decomposition (Borma et al. 1998, Crawshaw et al. 2018, Kirol et al. 2024, Macdonald, R.H. 1995, Preece et al. 2019).

Elevated DO concentrations have also been linked to increased rates of heavy-metal oxidation, converting metals from soluble to insoluble forms. This transformation reduces their biological availability and dissolved concentrations, resulting in improved water quality conditions (Atkinson et al. 2007, Kirol et al. 2024, Rabaev et al. 2021). Similarly, the increase in aerobic bacterial activity associated with higher DO concentrations suppresses anaerobic bacterial processes, thereby reducing the production of harmful gasses such as Hydrogen Sulfide improving overall water quality (Borma et al. 1998, Rabaev et al. 2021, Wang et al. 2025). Increased aerobic metabolism also contributes to the decomposition of organic detritus and pollutants, reducing the rate of debris accumulation and further limiting internal nutrient loading, and contributing to more stable and balanced surface water quality (Kenneth, I.A. 1983, Michael et al. 2025).

However, in systems containing sediments with significant metal-sulfide contamination, increased DO concentrations can temporarily elevate bioavailability of heavy metals as they are oxidized and transformed between chemical states (Michael et al. 2025, Ribaud et al. 2018). Furthermore, depending on the specific oxygenation strategy, poorly designed or implemented systems may cause sediment resuspension increasing the mobility of contaminants and organic nutrients and potentially counteracting intended improvements in water quality conditions (Kirol et al. 2024, Michael et al. 2025).

3.1.1 Reduction in Eutrophication

One key component of the improvement of overall surface water quality associated with increased DO concentration is the corresponding reduction in the risk and severity of eutrophication within shallow surface waterbodies. In systems with limited flow or vertical mixing, internal nutrient loading from accumulated organic sediments have been shown to be the dominant source of bioavailable nutrients (Andersen et al. 2017, Kenneth, I.A. 1983, Macdonald, R.H. 1995, Michael et al. 2025, Preece et al. 2019, Wang et al. 2025). Elevated DO levels have been shown to help mitigate eutrophication through several mechanisms, particularly by limiting nutrient flux across the sediment-water interface (Atkinson et al. 2007, Borman et al. 2017).

Elevated DO concentrations within the sediment-water boundary layer have been shown to suppress excessive nutrient cycling by reducing phosphorous and nitrogen release from sediments (Borman et al. 2017, Kenneth, I.A. 1983). Changes in key surface water quality conditions, notably pH, temperature, and DO, have been linked to changes in the rate of internal nutrient loading. Variations in DO changes as small as 1mg/L can alter Phosphorus release by approximately 25-37%, highlighting the sensitivity of nutrient flux to oxygen availability (Kirol et al. 2024, Shaw and Prepas 1990). Increased DO also promotes aerobic bacterial metabolism, which further reduces dissolved Phosphorus and Nitrate concentrations, two primary nutrients linked to algae bloom formation and eutrophication in shallow aquatic systems., (Atkinson et al. 2007, Macdonald, R.H. 1995, Michael et al. 2025, Shaw and Prepas 1990).

In addition, the reduction in dissolved nutrient concentrations and the enhancement of aerobic microbial activity have been linked to reductions in turbidity and improvements in water clarity and light penetration, conditions that promote natural submerged aquatic vegetation growth and enhanced overall ecological function (Andersen et al. 2017, Crawshaw et al. 2018). The establishment of a more naturalized aquatic condition can, in turn, help sustain elevated DO

levels and promote long-term stability and self-regulation of organic matter decomposition (Wang et al. 2025).

However, the extent of these benefits can be limited in systems with significant legacy nutrient loading from historically enriched or contaminated sediments. In such cases, elevated sediment nutrient concentrations may delay, reduce, or counteract the beneficial effects of increased DO concentrations on eutrophication control (Crawshaw et al. 2018, Preece et al. 2019, Ribaud et al. 2018).

3.2 Effects on Nutrient Cycling and Sediment Chemistry

Increased dissolved oxygen (DO) concentrations play a critical role in regulating nutrient cycling and sediment chemistry within shallow aquatic systems. In oxygen-limited environments, anaerobic conditions within surface sediments promote the release of nutrients and reduced compounds—particularly phosphorus, nitrogen, and various metal ions—back into the water column. This process, known as *internal loading*, can perpetuate eutrophic conditions even when external nutrient inputs are controlled (Andersen et al. 2017; Borman et al. 2017; Preece et al. 2019).

Enhanced DO concentrations establish more oxidized conditions at the sediment–water interface, resulting in the formation of insoluble metal–phosphate complexes that effectively immobilize phosphorus within sediments (Kirol et al. 2024; Shaw and Prepas 1990). These reduction-oxidation (redox) driven transformations also promote the oxidation of reduced nitrogen compounds such as ammonium (NH_4^+) into nitrate (NO_3^-), facilitating subsequent denitrification processes and further reducing the pool of bioavailable nitrogen (Atkinson et al. 2007; Crawshaw et al. 2018; Michael et al. 2025).

The transition from anaerobic to aerobic sediment conditions also alters the mobility of metals such as iron, manganese, and zinc. Under oxygenated conditions, these elements are oxidized into less soluble forms, thereby decreasing their bioavailability and potential toxicity to aquatic organisms (Rabaev et al. 2021; Wang et al. 2025). Conversely, in oxygen-depleted sediments, the reduction of iron and manganese oxides can release bound phosphorus and trace metals, reinforcing eutrophic conditions.

Sustained oxygenation can therefore stabilize sediment chemistry and improve long-term water quality, but these effects depend on maintaining sufficient DO penetration into the sediment layer. Seasonal temperature fluctuations, organic loading, and stratification can all influence

oxygen diffusion and microbial demand, potentially limiting the persistence of oxidation processes (Macdonald 1995; Preece et al. 2019). As such, successful oxygenation programs must account for sediment composition, water depth, and hydrologic turnover rates to ensure consistent and effective redox regulation.

3.3 Biological Effects of Increased Oxygenation

Increased dissolved oxygen (DO) concentrations can have profound effects on the biological communities within shallow surface water systems. Increased DO concentrations have been widely associated with enhanced habitat suitability for aquatic organisms and is a key determinant of species composition, productivity, and overall ecosystem function (Austin et al. 2019, Beutel et al. 1999, Preece et al. 2019). These enhancements can be realized as either an increase in the range of species that can be supported within the system or as improved habitat conditions for existing species diversity, leading to greater biodiversity and ecological stability (Barry et al. 2012, Bierlein et al. 2017). In eutrophic or hypoxic conditions, the absence of adequate DO often results in habitat degradation, loss of biodiversity, and altered food web dynamics. Conversely, sustained improvements in DO concentrations promote the recovery and stabilization of biological communities across multiple trophic levels (Atkinson et al. 2007; Crawshaw et al. 2018; Michael et al. 2025). Elevated DO levels are also attributed to reducing the risk of cyanobacteria and harmful algae blooms and lower the likelihood of large-scale fish kills resulting from anoxia or prolonged hypoxic events (Kirol et al. 2024, Michael et al. 2025, Preece et al. 2019, Wang et al. 2025).

Increased sediment oxygen availability is attributed to an increase in aerobic bacterial activity supporting greater benthic macro-invertebrate density and diversity, both of which are associated with accelerating the rate of organic compound decomposition and internal nutrient loading (Bierlein et al. 2017; Borman et al. 2017; Crawshaw et al. 2018; Kirol et al. 2024). Enhanced aerobic bacterial metabolism also inhibits sulfate-reducing anaerobic bacteria, decreasing the production of harmful gases such as hydrogen sulfide (H₂S) and methane (CH₄). Improvements in sediment level biodiversity, benthic macro-invertebrates and bacteria, contribute to improvements to sediment quality and promote conditions favourable for the growth of aquatic vegetation, thereby supporting natural revegetation processes (Barry et al. 2012, Beutel et al. 1999, Borman et al. 2017, Michael et al. 2025).

The increase in benthic and microbial diversity and vegetation growth is also linked to greater bioturbation, sediment mixing caused by benthic organisms, which enhances nutrient exchange

between sediment and water and reduces the bioaccumulation of toxic compounds (Andersen et al. 2017; Kenneth 1983; Shaw and Prepas 1990). This process supports the natural breakdown of previously sequestered organic material, further improving sediment health and overall system productivity. Despite these benefits, elevated DO concentrations can also result in higher Biological Oxygen Demand (BOD) due to the increased metabolic activity of aerobic organisms. If oxygenation systems are interrupted or discontinued, this heightened BOD can lead to rapid DO depletion, potentially reversing short-term improvements in water quality (Crawshaw et al. 2018; Kenneth 1983; Shaw and Prepas 1990). Therefore, sustained and well-managed oxygenation is essential to maintain long-term ecological stability and prevent secondary hypoxia.

3.4 Physical and System-Level Effects of Oxygenation

Beyond the chemical and biological benefits, increased dissolved oxygen (DO) concentrations can also influence the broader physical dynamics and stability of shallow surface water systems. Oxygenation affects water column stratification, circulation, temperature gradients, and gas exchange processes that collectively govern overall system health and resilience (Austin et al. 2019; Beutel et al. 1999; Kirol et al. 2024).

3.4.1 Thermal Stratification and Mixing

In shallow lakes, such as Swan Lake, temperature-driven stratification is typically weak or transient. However, during periods of high temperature and low wind activity, thermal layering can still occur, creating a hypolimnetic zone with reduced DO availability. Artificial or mechanical oxygenation can disrupt or prevent the formation of these anoxic bottom layers by enhancing vertical mixing and diffusive oxygen transfer (Barry et al. 2012; Borman et al. 2017; Preece et al. 2019). Improved circulation increases the uniformity of oxygen distribution throughout the water column, reduces stagnation, and limits the onset of localized hypoxia near the sediment–water interface.

Mechanical mixing or diffused aeration systems also promote the release of trapped gases, including carbon dioxide (CO₂) and methane (CH₄), while simultaneously enhancing reoxygenation through increased surface turbulence (Atkinson et al. 2007; Crawshaw et al. 2018). This process contributes to a more stable water column and moderates daily oxygen fluctuations commonly observed in eutrophic systems.

3.4.2 Sediment–Water Interface and Gas Exchange

Oxygenation at or near the sediment–water interface plays a critical role in regulating benthic fluxes and maintaining sediment redox stability. Enhanced DO penetration limits anaerobic processes, reducing the upward diffusion of reduced compounds such as ammonia (NH₃), ferrous iron (Fe²⁺), and hydrogen sulfide (H₂S) (Borman et al. 2017; Rabaev et al. 2021). Increased oxygen availability at this interface also promotes sediment consolidation, reducing resuspension and turbidity—factors that otherwise exacerbate internal nutrient loading (Kirol et al. 2024; Michael et al. 2025).

Increased turbulence and mixing further improve gas exchange efficiency at the air–water boundary, increasing atmospheric oxygen transfer and promoting the release of volatile compounds that can otherwise impair water quality or produce odours (Andersen et al. 2017; Wang et al. 2025).

3.4.3 Long-Term System Stability

By improving water column circulation, moderating stratification, and enhancing redox stability, oxygenation can substantially increase the overall resilience of shallow aquatic ecosystems. Enhanced DO levels help maintain ecological balance, prevent the re-establishment of hypoxia, and support positive feedback loops that reinforce improved biological and chemical conditions (Beutel et al. 1999; Preece et al. 2019).

However, the physical benefits of oxygenation are highly dependent on site-specific factors, including lake morphology, depth, hydrologic residence time, and organic loading. In small, shallow, and enclosed systems such as Swan Lake, oxygenation can be particularly effective, but long-term success depends on consistent operation, appropriate system design, and integration with broader watershed nutrient management strategies (Michael et al. 2025; Wang et al. 2025).

4.0 Relevance of Increased Oxygen to Swan Lake

Swan Lake is a Hyper-eutrophic, shallow waterbody characterized by recurring algae blooms and persistently low overall DO concentrations. Historic and ongoing nutrient loading attributed to Canada Geese activity and stormwater/surface water runoff has resulted in substantial sediment accumulation and ongoing internal nutrient loading, contributing to ongoing elevated Phosphorus levels and sustaining eutrophic conditions. The absence of natural inflows and outflows, coupled with limited water depths, restricts natural circulation and water stratification. These factors contribute to stagnant conditions that amplify the effects of harmful algal and cyanobacteria blooms and limit surface mixing that would otherwise support natural oxygenation.

The aquatic community within Swan Lake is currently dominated by tolerant warmwater fish species and exhibits low biodiversity, sparse aquatic vegetation, and minimal bioturbation—conditions typical of degraded habitat quality and poor surface water function. Increasing DO concentrations within Swan Lake have the potential to contribute significantly to the improvement of both overall water quality conditions and aquatic habitat conditions. Elevated DO levels are expected to enhance aerobic bacterial activity, which, in combination with chemical processes affecting Phosphorus and Organic nutrient cycling, would accelerate the decomposition of organic material and improve nutrient turnover. This, in turn would, reduce internal nutrient loading, lower surface water Phosphorus concentrations, contributing to a decrease in the risk of eutrophication and algae bloom formation. Sustained DO enhancement would be further expected to contribute to improved surface water clarity and promote natural aquatic vegetation growth, further reinforcing natural nutrient cycling and stabilization of lakebed sediments.

Higher DO concentrations would additionally improve habitat suitability for aquatic fauna by reducing the risk of hypoxia-induced stress and supporting a wide range of fish and invertebrate species. Enhanced benthic macroinvertebrate activity and vegetation establishment would provide improved substrate conditions, increased habitat complexity, and more stable ecological interactions.

Given the organic nutrient compounds found throughout Swan Lake, primarily from stormwater and surface runoff, as well as more natural sources, such as high Canada Geese populations, it is also expected that elevated DO levels will facilitate the natural oxidation and decomposition of accumulated organic and in-organic contaminants within the sediment as the oxidation of heavy

metals and organic compounds, would reduce their bioavailability and toxicity, thereby contributing to overall water quality improvements.

However, improvements in water quality may occur gradually due to substantial nutrient and contaminate load stored in the existing sediments. Moreover, increased biological activity associated with higher DO concentrations may elevate the systems biological oxygen demand if oxygenation measures were ceased abruptly, rapid DO depletion could occur, potentially reversing short-term gains in water quality.

Importantly, while increased DO concentrations can have a wide range of potential ecological benefits, oxygenation alone may not be sufficient to fully mitigate internal nutrient loading or reverse eutrophic conditions in systems with significant historical enrichment. Therefore, induced oxygenation should be implemented in conjunction with broader overall lake rehabilitation and watershed management strategies, including nutrient source control, sediment management, and habitat restoration, to ensure sustainable and long-term improvement in water quality within Swan Lake.

5.0 Summary of Oxygenation Management Approaches

A range of chemical and engineered oxygenation and aeration techniques are available to potentially enhance DO concentrations in lakes and ponds. Each strategy operates through different mechanisms and carries unique design and operational considerations that influence its suitability for a given site. The selection of an appropriate system depends on site-specific factors, including lake morphology, depth, sediment composition, nutrient sources, and hydrologic connectivity. For Swan Lake, which is a shallow, enclosed and highly eutrophic, the most feasible options are those that provide consistent oxygen delivery and promote mixing without excessive sediment disturbance.

5.1 Artificial or Engineered Aeration

One of the simplest and most commonly applied techniques to increase DO concentrations in surface water is **Artificial or Engineered Aeration**, which enhances DO through physical surface water turbulence or circulation increasing air-water gas exchange or air bubbles and diffusers to induce vertical mixing.

The most common form of engineered aeration, **Diffused Aeration**, or “bubbler”, introduces air through diffuser systems to promote gas exchange and induce vertical mixing between water layers (Austin et al. 2019). These systems can be effective at reducing localized stagnation in small surface waterbodies and can increase DO concentrations near the sediment-water interface (Barry et al. 2012). Elevated sediment DO has been shown to increase the effectiveness at controlling internal Phosphorus loading by stimulating aerobic bacterial activity within surficial sediments (Beutel et al. 1999, Bierlein et al. 2017). Hypolimnetic aeration is generally considered a relatively low-maintenance and effective method for mitigating hypoxia in systems with minimal stratification; however, its ability to affect large surface areas or substantially improve whole-lake circulation is limited (Barry et al. 2012).

5.1.1 Diffused Aeration Systems

Diffused aeration systems are among the most widely used and adaptable oxygenation techniques for improving dissolved oxygen (DO) concentrations in lakes and ponds. These systems operate by releasing compressed air or pure oxygen through diffuser heads, stones, or perforated tubing placed near the lake bottom. As air bubbles rise through the water column, they promote vertical circulation, enhance gas exchange, and facilitate oxygen diffusion throughout the system (Austin et al. 2019; Beutel et al. 1999).

Diffused aeration systems are particularly effective in small to medium-sized lakes where natural circulation is limited but complete thermal stratification is absent. The continuous release of fine air bubbles increases oxygen transfer efficiency while providing gentle water column mixing that prevents stagnation and improves DO distribution. In addition to raising DO concentrations in the water column, these systems help maintain oxidized conditions at the sediment–water interface, thereby reducing internal nutrient loading and promoting aerobic microbial activity (Barry et al. 2012; Bierlein et al. 2017; Kirol et al. 2024).

Diffused systems are less disruptive to sediments and can be operated continuously with low noise and modest energy requirements. They can also be configured for seasonal or year-round operation, allowing adjustments based on temperature, biological oxygen demand (BOD), and ice-cover conditions. However, in very shallow or irregularly shaped basins, the effectiveness of diffused aeration may be reduced due to limited vertical mixing potential and uneven bubble distribution. Careful diffuser placement is therefore critical to ensure adequate coverage and to avoid localized zones of low oxygen or excessive turbulence. If operated continuously diffused systems can enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. When used in combination with rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—can contribute to improved long-term water quality conditions.

For Swan Lake, diffused aeration represents a feasible and practical option for improving DO concentrations. Multiple diffusers positioned in the deeper and more stagnant zones could promote moderate mixing and oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously at low intensity, such a system would enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

5.1.2 Gravity (Cascade) Aeration,

Gravity Aeration, also referred to as cascade aeration, is a form of mechanical aeration that employs artificial waterfalls or stepped flow structures, along with pumping systems, to enhance oxygenation by increasing the waters exposure to the atmosphere and increase the air-water gas exchange. Gravity aeration is relatively low-tech, energy efficient, and effective at increasing DO concentrations within a localized zones while promoting increased circulation

improvements throughout the water column (Kirol et al. 2024). Gravity Aeration, remains limited in its capacity to influence large surface areas or resolve lake or system-wide oxygen defects. (Kirol et al. 2024).

While gravity aeration methods are generally effective in small or confined systems, their performance can be reduced during periods of high temperature or elevated biological oxygen demand (BOD) associated with high organic nutrient concentrations (Borman et al. 2017). In addition, improper system design or overpowered aeration can lead to sediment resuspension, releasing nutrients and contaminants and increasing turbidity.

If employed correctly gravity aeration systems have the potential to enhance surface DO conditions and induce localized mixing, contributing to increased aerobic microbial activity, and gradually reduce internal nutrient loading. When used in combination with rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—can contribute to improved long-term water quality conditions.

Gravity aeration can lead to a dramatic increase in DO concentrations within localized areas and, if properly designed and applied, can minimize sediment disturbance. However, given the overall surface area of Swan Lake, lack of both stratification and high internal nutrient loading, achieving lake-wide oxygen enhancement would require significant infrastructure investment. Long-term improvements in surface water quality are unlikely to be realized through mechanical aeration alone without complementary rehabilitation measures to address nutrient-enriched sediments and reduce ongoing stormwater nutrient inputs.

5.1.3 Fountain Aeration,

Fountain Aeration, is a form of mechanical aeration where water is pumped vertically into the air, increasing the waters exposure to the atmosphere promoting air-water gas exchange. As the oxygenated water droplets return to the water surface, they increase surface disturbance, and facilitate the diffusion of oxygen into the water column (Hao et al. 2021; Zebek 2014).

Fountain aeration systems can be effective in shallow small to medium-sized lakes where natural circulation is limited and thermal stratification is absent (Abu Hasan et al. 2025; Howley et al. 2021). The continuous fountaining of small water droplets can increase oxygen transfer efficiency and maintains surface agitation, which can disrupt algae accumulations and reduce the frequency of harmful algae blooms (Aytac et al 2024; Hoa et al. 2020). These systems are

relatively quiet, energy-efficient, and cause minimal sediment disturbance, making them suitable for both functional and aesthetic applications in urban or recreational waterbodies.

However, Fountain Aeration systems have a limited capacity to improve oxygenation at depth, and their effectiveness in addressing whole-lake oxygen deficits is constrained by their restricted mixing range and droplet dispersion (Zebek 2024). Performance can also decline during periods of high air or water temperatures, when oxygen solubility decreases (Tuna Kelestemur et al. 2024). Additionally, fountain aeration can lead to a slight increase in surface water temperatures and can only operate under ice-free conditions (Zebek 2014).

The effectiveness of fountain aeration systems is limited by the fountain size, spray pattern and pump capacity, which determines the degree of mixing and oxygenation achieved. Optimal placement and spacing is therefore critical to ensure adequate coverage and to avoid localized zones of low oxygen or excessive turbulence (Henny et al. 2019; Sinclair et al. 2020).

When operated continuously, fountain aeration systems can enhance surface DO, stimulate aerobic microbial activity, and contribute to gradual improvements to in sediment condition and reduce internal nutrient loading. However, given their limited vertical mixing, fountain systems are most effective when used in combination with broader rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—to improve long-term water quality conditions and reduce the effects of elevated biological oxygen demand (BOD) associated with high organic nutrient concentrations (Hao et al. 2021; Zebek 2014).

5.2 Chemical Oxygenation

Chemical Oxygenation is a less common but more direct method of increasing DO concentrations in stagnant or poorly circulated surface waterbodies. This approach involves oxygen-releasing compounds such as Calcium Peroxide, or oxidizing agents that influence sediment level chemical interactions and promote natural oxygenation processes (Barry et al. 2012, Borman et al. 2017). The use of Calcium Peroxide as an oxygen release agent as been proposed by the Friends of Swan Lake Park as a potential method to increase DO levels throughout Swan Lake, however widespread application to address low DO levels are still in the experimental phase and has been rejected by the City of Markham in favor of managing the root cause of nutrient loads and the opinion that the DO levels are above their internal guidelines and no further intervention is needed (Siembida-Losch 2022 and AECOM 2023).

Chemical oxygen-release agents function by slowly decomposing to elemental oxygen, which increase DO levels in the surrounding water and sediment. These materials can be highly effective in addressing prolonged hypoxic or anoxic conditions, particularly in locations with limited physical access or where continuous mechanical aeration is impractical (Kenneth, I.A. 1983). These release agents can also promote aerobic bacterial activity at the sediment-water interface, controlling the release of nutrients thereby reducing internal nutrient loading by suppressing phosphorus and nitrogen release from nutrient-enriched substrates (Barry et al. 2012, Borman et al. 2017, Preece et al. 2019, Wang et al. 2025).

However, the effectiveness and longevity of these treatments depends heavily on accurate calibration of specific dosage rates to match site-specific oxygen demand and internal nutrient loading. Over or under application can result in limited effectiveness or temporary improvements followed by rapid re-oxygen depletion and as such it can be difficult to accurately apply for larger surface water bodies (Bierlein et al. 2017, Ribauda et al. 2018). Moreover, while chemical oxygenation can provide localized oxygenation and enhance sediment redox stability, it does not improve water column mixing or circulation.

In addition to direct oxygen-release compounds, chemical oxidants (e.g., nitrate-based amendments or other oxygen donors) can be applied to modify redox conditions within sediments, promoting aerobic microbial processes and inhibiting the release of reduced compounds and nutrients (Kenneth 1983; Preece et al. 2019). These treatments can be effective in reducing internal nutrient loading and limiting algal bloom formation; however, their successful implementation requires a detailed understanding of sediment geochemistry, nutrient cycling, and seasonal oxygen dynamics

Within Swan Lake, chemical oxygenation could provide a targeted, low-disturbance approach to increase DO concentrations, particularly in sediment-rich or inaccessible areas. This technique would avoid sediment resuspension and could sustain elevated DO levels over an extended period to time to address seasonally low DO levels. However, precise chemical and dosage calibrations would be essential to ensure long-term effectiveness. While chemical oxygenation offers broader special treatment coverage than localized mechanical systems, it does not address the lack of natural mixing or circulation within Swan Lake, nor the underlying cause of eutrophication. Consequently, chemical oxygenation would be best employed as a supplemental measure within an integrated rehabilitation program that includes nutrient management and physical oxygenation methods.

5.3 Destratification and Mixing

Destratification and induced Mixing represents a less common but potentially effective approach to improve DO levels within shallow surface water bodies (Beutel et al. 1999). At the most basic level, destratification increases DO concentrations by inducing water circulation and promoting mixing between water layers, thereby improving oxygen distribution throughout the water column, including the sediment-water interface (Crawshaw et al. 2018, Macdonald, R.H. 1995, Preece et al. 2019).

By breaking down thermal or chemical stratification, destratification reduces internal stagnation, disrupts algae blooms and minimizes the formation of anoxic zones. This allows for enhanced gas exchange at the air-water interface, promotes natural oxygenation of organic pollutants and limits internal nutrient loading from sediments (Austin et al. 2019, Beutel et al. 1999, Kirol et al. 2024). The effectiveness of destratification can be highly dependent on shoreline morphology, bathymetric contours, and rate of recirculation as these factors influence the extent of water movement and the resulting increase in dissolved oxygen (DO) concentrations. Achieving meaningful DO improvements generally requires substantial surface water agitation (Beutel et al. 1999).

Destratification is generally considered less effective at increasing DO concentrations when compared to targeted mechanical aeration systems, however it offers broader benefits in addressing stagnation, circulation deficiencies, and hypoxic zone formation (Rabaev et al. 2021). Similar to mechanical aeration improvements dependent on continuous operation, as DO levels often decline rapidly once circulation ceases. Additionally, destratification can lead to a moderate increase in overall surface water temperatures, which can have unanticipated impacts to habitat conditions for native fish and aquatic wildlife (Kenneth, I.A. 1983). The installation and operation of destratification systems in larger waterbodies can require significant infrastructure investment and energy inputs to achieve meaningful DO improvements (Macdonald, R.H. 1995).

For Swan Lake, destratification such as that potentially achieved from the circulation of surface water via the Swan Lake North Pond Channel, has the potential to increase the DO concentrations by promoting limited current flow and reducing internal lake stagnation. This may also help suppress algae bloom formation and improve localized surface water conditions. However, due to Swan Lakes overall shallow water depths, limited stratification, and high organic oxygen demand, destratification alone is unlikely to achieve substantial, system-wide

increase in DO concentrations. The expected low volume recirculation would not generate sufficient surface agitation or flow to meaningfully enhance natural oxygenation.

Within shallow weakly stratified environments, it can support additional management measure to improve water movement and reduce stagnation and if implemented alongside complementary oxygenation and nutrient management strategies result in lasting water quality improvements.

Because Swan Lake is shallow and only weakly stratified, temperature increases associated with destratification are not expected to adversely affect resident warmwater fish or aquatic invertebrate communities. Overall, destratification could serve as a supportive management measure to improve water movement and reduce stagnation but should be implemented alongside complementary oxygenation and nutrient management strategies to achieve significant and lasting water quality improvements.

6.0 Summary of Oxygenation Methods and Comparative Feasibility

A variety of oxygenation and aeration techniques are available to enhance dissolved oxygen (DO) concentrations in surface waterbodies. Each method operates through distinct physical or chemical mechanisms and presents varying levels of effectiveness depending on site-specific conditions such as depth, morphology, sediment quality, and nutrient dynamics.

For Swan Lake, with its lack of stratification and current flows, **Diffused Aeration** represents a potentially feasible option for improving DO concentrations. Multiple diffusers positioned in the deeper and more stagnant zones could promote moderate mixing and oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously at low intensity, such a system would enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
 - Promote moderate mixing and oxygenation without disturbing sediments;
 - Enhance both surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading,
 - Effective in shallower lake environments <5m lacking stratification.
- Cons:
 - Localized benefits surrounding diffusers - adequate coverage required to avoid localized zones of low oxygen;
 - Would require complementary rehabilitation measures, and
 - Maintenance required for long-term function.

For Swan Lake with its lack of stratification and current flows, **fountain aeration** represents a potentially feasible option for improving DO concentrations. Multiple fountains positioned to cover a significant portion of the surface area could promote oxygenation without disturbing fine, nutrient-rich sediments. When operated continuously such a system would enhance surface DO, inhibit algae bloom formation, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:

- Promote moderate oxygenation without disturbing sediments;
- Enhance surface DO, stimulate aerobic microbial activity, inhibit algae bloom formation, and gradually reduce internal nutrient loading,
- Cons:
 - Localized benefits surrounding diffusers - adequate coverage required to avoid localized zones of low oxygen;
 - Would not provide year round oxygenation;
 - Would require complementary rehabilitation measures;
 - Maintenance required for long-term function.

Chemical Oxygenation represents a potentially feasible option for improving DO concentrations throughout Swan Lake. Successful implementation would require the use of carefully selected and calibrated chemical treatments to ensure adequate coverage and sustained oxygen release throughout Swan Lake while minimizing the formation of localized hypoxic or anoxic zones.

When properly applied, chemical oxygenation could promote both surface and sediment level oxygenation, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
 - Promote moderate oxygenation without disturbing sediments;
 - Enhance surface and sediment DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading;
 - Continuous oxygenation with minimal maintenance.
- Cons:
 - Requires specialist chemical blends to ensure appropriate and continuous oxygenation;
 - Would require complementary rehabilitation measures;
 - Would require repeated chemical treatments for continuous long-term function.

Destratification is a logistically complex potential beneficial strategy for improving overall water quality conditions within Swan Lake. Despite a lack of thermal stratification within Swan Lake,

this approach would primarily address stagnation, circulation deficiencies, and the formation of anoxic zones though it has a less direct influence on DO concentrations.

Circulating surface water through the Swan Lake North Pond Channel has the potential to increase the DO concentrations by promoting limited current flow, disrupting weak thermal layering, and reducing internal lake stagnation. When properly implemented, destratification can promote oxygenation at the sediment-water interface, stimulate aerobic microbial activity, and contribute to the gradual reduction of internal nutrient loading. Integration with complementary rehabilitation measures—such as sediment management, nutrient source reduction, and shoreline naturalization—would maximize long-term water quality improvements.

- Pros:
 - Minimize anoxic zone formation and address overall lake stagnation;
 - Enhance sediment level DO, stimulate aerobic microbial activity, and gradually reduce internal nutrient loading.
- Cons:
 - Logistically complicated to implement;
 - Maintenance required for long-term function
 - Minimal overall DO influences;
 - Would require complementary rehabilitation measures;

Method	Mechanism of Action	Advantages	Limitations	Feasibility for Swan Lake
Mechanical Aeration	Agitates or circulates water at the surface to enhance gas exchange and disrupt localized stagnation.	Immediate DO improvement; simple installation; visible circulation.	Limited spatial reach; energy-intensive; risk of sediment resuspension.	Effective only in localized zones; significant infrastructure needed for lake-wide benefit.
Gravity (Cascade) Aeration	Form of mechanical aeration, artificial waterfall and flow structures, disrupt localized stagnation and promote circulation.	Immediate DO improvement; low-tech, and energy efficient.	Limited spatial reach; limited ability at addressing large area; risk of sediment resuspension.	Effective only in localized zones; significant infrastructure needed for lake-wide benefit.
Diffused Aeration	Releases compressed air through submerged diffusers to promote vertical mixing and oxygen transfer.	Gentle, uniform oxygenation; low disturbance; energy-efficient; adaptable to seasonal use.	Requires careful diffuser placement; effectiveness reduced in very shallow areas.	Highly suitable; offers broad coverage and sustained oxygenation when operated continuously.
Fountain Aeration	Pumping water through surface level diffusers into the air to promote gas exchange and surface agitation.	Uniform oxygenation; low disturbance; simple installation.	Limited spatial reach; requires careful fountain placement; non-functional during winter months.	Highly suitable; simple installation; offers sustained oxygenation when operated continuously.
Chemical Oxygenation	Introduces oxygen-releasing or oxidizing compounds that supply elemental oxygen or modify sediment redox conditions.	Direct oxygen delivery; long-lasting effect; no mechanical disturbance.	Requires precise dosing; limited circulation benefit; may provide only temporary improvement.	Moderate feasibility; useful as supplemental treatment for localized low-oxygen zones.
Destratification / Mixing	Induces circulation to break down stratification and promote natural oxygenation through gas exchange.	Reduces stagnation; minimizes hypoxic zone formation; enhances natural mixing.	Limited DO increase; potential warming; continuous operation required.	Partially feasible; could aid circulation but unlikely to raise overall DO significantly.

7.0 Conclusions and Recommendations

Within Swan Lake, any management approach intended to increase DO concentrations must be designed not only to address existing DO deficiencies but also anticipate increases in biological oxygen demand (BOD) that will result from enhanced biological and microbial activity following oxygenation. As oxygen availability improves, aerobic bacteria, benthic invertebrates, and aquatic vegetation will become more active, increasing oxygen consumption and temporarily offsetting some of the initial gains in DO. Accordingly, any oxygenation strategy must account for these feedback effects and be implemented as part of a long-term, adaptive rehabilitation program.

Importantly, effective DO enhancement within Swan Lake must also target the underlying causes of poor surface water quality, Specifically, historic and ongoing nutrient and containment loading from high Canada Geese populations, stormwater inputs and the accumulation of nutrient-rich organic sediments. High organic matter concentrations, low sediment oxygen concentrations, and anaerobic bacterial processes may work against active oxygenation programs in Swan Lake. These conditions can consume oxygen more rapidly than it is introduced, thereby slowing the realization of measurable improvements reducing the effectiveness of direct oxygenation by continuously releasing nutrients and consuming available oxygen.

While active oxygenation can be highly effective in addressing short-term hypoxia and improving localized water quality, it rarely provides lasting improvements unless combined with integrated watershed and sediment management actions. Stand-alone oxygenation systems typically require continuous operation to maintain benefits, as discontinuation can lead to a rapid decline in DO concentration, often below pre-treatment level, due to increased BOD and residual nutrient release.

Increased oxygenation in shallow, nutrient-rich systems such as Swan Lake can lead to significant improvements, including:

- Reduced internal nutrient loading and phosphorus release from sediments.
- Decreased bioavailability of heavy metals through oxidation.
- Improved surface water clarity and reduced frequency of harmful algal blooms.
- Enhanced biological diversity and productivity through improved aerobic habitat conditions.

However, these benefits are typically realized gradually, as the system responds to improved redox conditions and enhanced biological cycling. Regardless of the oxygenation strategy employed, elevated biological oxygen demand (BOD) can also lead to a sudden decline in dissolved oxygen concentrations, potentially to levels lower than those observed prior to treatment, if oxygenation programs are discontinued without addressing the underlying causes of poor water quality. Effective long-term management will therefore require sustained oxygenation, regular monitoring, and adaptive operational adjustments to maintain DO levels sufficient to counteract high BOD and sediment oxygen demand.

7.1 Oxygenation Program Considerations

Oxygenation represents a viable and effective approach to improving surface water quality and aquatic habitat conditions within Swan Lake. Diffused aeration or fountain aeration systems would likely provide the most balanced combination of performance, reliability, and cost-effectiveness for this small, shallow, and nutrient-enriched lake. When paired with watershed-level nutrient management and ecological restoration efforts, these systems can form the foundation of a long-term strategy to enhance aquatic health, reduce eutrophication, and restore more natural lake function.

However, oxygenation alone will not fully address all water quality deficiencies or the underlying causes of degradation. To improve the effectiveness and sustainability of oxygenation measures, several key factors should be considered when developing and implementing an oxygenation program for Swan Lake.

- **Address Natural Mixing Limitations:** Any oxygenation program should aim to overcome the lack of natural circulation within Swan Lake to ensure adequate exposure of all areas to elevated DO concentrations.
- **Uniform Application:** Oxygenation should be applied uniformly across the lake to prevent the formation of localized hypoxic or anoxic zones.
- **Integrated Management Approach:** Oxygenation cannot resolve the underlying causes of poor surface water quality and should be implemented in conjunction with broader rehabilitation measures that address both historical and ongoing nutrient and contaminant inputs.
- **Continuous Operation:** Consistent, low-intensity operation is preferable to intermittent high-output cycles, as sudden fluctuations in DO can destabilize the system and increase BOD demand.

- **Hydrologic Connectivity:** Recirculation of water through the north channel is expected to provide only limited improvement in DO levels unless underlying nutrient concentrations are simultaneously addressed.
- **System Design:** System layout should provide full spatial coverage, including deeper basins and areas of low circulation, while avoiding disturbance of fine, nutrient-rich sediments.
- **Operational Schedule:** Continuous, steady operation will help maintain stable oxygen levels and minimize fluctuations in BOD and redox potential.
- **Monitoring Program:** Ongoing monitoring of DO, temperature, turbidity, and phosphorus concentrations should accompany installation to evaluate system effectiveness and inform adaptive management.
- **Integration with Rehabilitation Efforts:** Oxygenation should complement a broader restoration plan that includes sediment nutrient management, stormwater inflow treatment, and shoreline naturalization to improve long-term system stability.

In summary, successful improvement of water quality within Swan Lake will depend on an integrated approach that combines active oxygenation with nutrient load reduction, sediment management, and ecological restoration. These combined measures will enhance dissolved oxygen concentrations, promote stable redox conditions, and foster a more balanced and resilient aquatic ecosystem.

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Appendix I
Key Findings and References

Key Finding	Summary	Source
<p>Improvement in Surface Water Quality</p>	<ul style="list-style-type: none"> Significant surface water quality and aquatic habitat improvements have been linked to increased DO concentrations within small highly eutrophic water bodies. Reduction in nutrient release (Nitrogen - N, Iron – Fe and P) from high concentration sediments. Control and limit internal nutrient loading from high nutrient concentration sediments. Increase in heavy metal mobility, the conversion from soluble to insoluble forms, and biological availability. Increased aerobic microbial activity and organic pollutant decomposition. Increased benthic macro-invertebrate activity and diversity. Increased organic material decomposition and improvement in substrate suitability to support aquatic vegetation. In areas of significant metal sulfide contamination, temporary increase in biological availability of heavy metals. Improvements in surface water clarity and decrease in turbidity Reduction in risk of algae bloom accumulation. Can be linked to resuspension of contaminated sediment if not applied correctly. Effectiveness of increased DO on improving water quality limited by historic and ongoing nutrient loading. Not a perfect solution to offset historic high concentration organic nutrient loading. 	<p>Andersen et al. 2017 Atkinson et al. 2007 Borma et al. 1998 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Michael et al. 2025 Preece et al. 2019 Rabaev et al. 2021 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025</p>
<p>Reduction of Eutrophication</p>	<ul style="list-style-type: none"> Decreased overall risk of eutrophication. Limits internal nutrient loading. Limit algae bloom formation and reduce the risk of harmful algae blooms. Reduce anaerobic bacterial activity limits accumulation and release of harmful gasses (i.e. H₂S, CH₄). Improvement in water clarity and biological activity and natural vegetation growth. Increased DO, pH and water temperature are all strongly linked to changes in sediment Phosphorus release, 1mg/L change in DO reflect with a corresponding 25-37% change in Phosphorus loading. 	<p>Andersen et al. 2017 Atkinson et al. 2007 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Michael et al. 2025 Preece et al. 2019 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025</p>

	<ul style="list-style-type: none"> Legacy Phosphorus release is strongly linked to delays (or opposition) to improvements in surface water quality following increases in DO levels. 	
Enhancement of Aquatic Life	<ul style="list-style-type: none"> Improved habitat suitability with increased surface water DO concentrations. Reduced risk of fish kills or formation of hypoxic environments Inhibition of harmful algae blooms and cyanobacteria growth. Increased aerobic microbial activity and organic pollutant decomposition. Increased benthic macro-invertebrate activity and diversity. Reduce anaerobic bacterial activity limits accumulation and release of harmful gasses (i.e. H₂S, CH₄). Increased organic material decomposition and improvement in substrate suitability to support aquatic vegetation. Increased in bioturbation depths Decreased bioaccumulation of toxic compounds. Increased DO is associated with increases in Biological Oxygen Demand. 	<p>Andersen et al. 2017 Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999 Bierlein et al. 2017 Borman et al. 2017 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Michael et al. 2025 Preece et al. 2019 Ribaudo et al. 2018 Shaw and Prepas 1990 Wang et al. 2025</p>
Mechanical Aeration	<ul style="list-style-type: none"> Increased DO through surface water aeration and agitation. Simple but effective. Limited influence on addressing stratification and mixing. Requires specific oxygenation strategies, Hypolimnetic aeration, to directly oxygenate substrate levels. Increased sediment/water boundary DO levels associated with increased effectiveness at controlling Phosphorus release and improve effects on promoting aerobic bacterial activity. Generally, less effective in high temperature areas or areas with high Biological Oxygen Demand, and high nutrient loads. Can be effective at addressing internal Phosphorus loading over a limited geographic area, generally limited effectiveness in large surface area environments. Limited effect on overall stagnation. Can be linked to contaminated sediment resuspension following improper implementation. 	<p>Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999 Bierlein et al. 2017 Borman et al. 2017 Kirol et al. 2024</p>
Gravity (Cascade) Aeration	<ul style="list-style-type: none"> Low-tech alternative to conventional mechanical aeration using artificial waterfalls, limited improvement on surface water mixing. Increased DO through increased air-water gas exchange. 	<p>Austin et al. 2019 Barry et al. 2012 Beutel et al. 1999</p>

	<ul style="list-style-type: none"> • Increased sediment/water boundary DO levels associated with increased effectiveness at controlling Phosphorus release and improve effects on promoting aerobic bacterial activity. • Generally, less effective in high temperature areas or areas with high Biological Oxygen Demand, and high nutrient loads. • Can be effective at addressing internal Phosphorus loading over a limited geographic area, generally limited effectiveness in large surface area environments. • Limited effect on overall stagnation. • Can be linked to contaminated sediment resuspension following improper implementation. 	<p>Borman et al. 2017 Kirol et al. 2024.</p>
<p>Chemical Oxygenation</p>	<ul style="list-style-type: none"> • Increase DO level through direct chemical oxygen or induced oxygenation reactions. • Direct oxygen release agents (e.g. calcium peroxide) release oxygen over an extended period with a lack of ongoing infrastructure maintenance. • Increased aerobic bacterial activity and reduced internal nutrient loading. • Useful to address hypoxic conditions in difficult to access sites without the risk of sediment resuspension. • Dosage rates dependent on existing and future oxygen demands. • Difficult to accurately apply for larger surface water bodies. • Induced oxygenation addresses limiting chemical factors common to eutrophic environments. • Induces natural chemical oxygenation, highly dependent on a thorough understanding of the internal nutrient cycling processes and specific nutrient loading rates. 	<p>Barry et al. 2012 Bierlein et al. 2017 Borman et al. 2017 Kenneth, I.A. 1983 Preece et al. 2019 Ribaud et al. 2018 Wang et al. 2025</p>
<p>Destratification / Mixing</p>	<ul style="list-style-type: none"> • Destratification induced mixing and current flow. • Increased current flow and circulation of surface water and lake bottom water layers. • Allows natural oxygenation of surface water and circulation of higher DO water to low DO areas. • Useful to address internal lake stagnation and minimize the formation of anoxic zones. • Highly complicated to implement in large surface water bodies. • Does not directly increase DO levels. • Dependent on natural oxygenation capacity of an environment. 	<p>Austin et al. 2019 Beutel et al. 1999 Crawshaw et al. 2018 Kenneth, I.A. 1983 Kirol et al. 2024 Macdonald, R.H. 1995 Preece et al. 2019 Rabaev et al. 2021</p>

	<ul style="list-style-type: none">• Less effective in high water temperature environments.• Can increase overall surface water temperatures.	
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