Prospect Lake Design, Colorado Springs, Colorado

March 2023

Report to

City of Colorado Springs

Prepared by

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Executive Summary

The City of Colorado Springs has contracted EcoResource Solutions (ERS) to design an aeration system for Prospect Lake. The main objective is to implement an aeration system and injection system capable of distributing liquid treatment to the lake to combat blue green algae blooms and fish kills. This report includes an introduction to lake systems and aeration, breakdown of two potential systems; Design 1 and Design 2, comparison of the systems, and itemization of system components.

1.0 Lake Systems Introduction

A lake's health is determined by the quality of its water, which is affected by various factors. These include: the amount of pollution in the water, the amount of sediment, the presence of harmful algal blooms, and the abundance of aquatic life. Pollution can be caused by runoff from agricultural activities, industrial activities, runoff from urban areas, and other sources. Sediment can be caused by erosion, construction activities, and other sources. Harmful algal blooms can occur when there is an overload of nutrients in the water, such as phosphorus and nitrogen. This can lead to a decrease in oxygen levels, which can be harmful to fish and other aquatic life.

Dissolved oxygen – oxygen molecules dissolved in water – is a major indicator of water quality. Like the air we breathe, the survival of aquatic life depends on a sufficient level of oxygen dissolved in water. When it drops below levels necessary for sustaining aquatic life, it becomes a significant water quality impairment, often referred to as low dissolved oxygen (DO). Unlike air, which is normally about 21 percent oxygen, water contains only a tiny fraction of a percentage of dissolved oxygen. Low dissolved oxygen (DO) primarily results from excessive algae growth caused by phosphorus or nitrogen. As the algae die and decompose, the process consumes dissolved oxygen. This can result in insufficient amounts of dissolved oxygen available for fish and other aquatic life. Die-off and decomposition of submerged plants also contributes to low dissolved oxygen. The process of decomposition is called Carbonaceous Biochemical Oxygen Demand (CBOD). Sources of phosphorus include discharges from municipal and private wastewater treatment, cropland and urban storm water runoff, and natural decay of vegetation. Direct discharge of pollutants from point source and nonpoint sources into a river segment add to its CBOD loadings, creating an oxygen demand that may depress DO below acceptable concentrations.

Lake aeration is a process of introducing oxygen into a body of water, typically a lake, to improve its water quality. Aeration is usually done through the use of an aerator, which is an apparatus that uses air, water, and other substances, such as oxygen or carbon dioxide, to oxygenate the water. The aerator works by forcing air bubbles through the lake water. The oxygen in the air bubbles then diffuses into the lake, which helps to reduce the levels of pollutants and decomposing organic matter in the water. Aeration also helps to increase the number of beneficial bacteria in the lake, which can help to improve water clarity. Lake aeration is typically used to reduce the effects of eutrophication, which is when a body of water becomes overly enriched with nutrients, leading to an increase in algae and aquatic weed growth. It is also used to reduce the amount of organic matter in the lake, which can lead to the growth of toxic algae and low oxygen levels. Additionally, it can reduce the levels of toxic pollutants, such as mercury and lead, which can be dangerous to humans and other organisms.

Oxygenation can help reduce undesirable algae by facilitating the conversion of phosphorus to forms that do not sustain algae growth. It can also adjust pH and other related water quality parameters to help improve the growth of fish, native organisms and healthy green phytoplankton – rather than cyanobacteria species, which can be toxic to humans and wildlife. Most importantly, improved oxygenation and water circulation can help reduce the accumulation of sediment at the bottom of the waterbody, which is one of the most common signs of an aging pond. As a result, the waterbody is naturally healthier and is less likely to require algaecide treatments or costly excessive lake sediment removal.

Submersed diffused aeration systems can help oxygenate the lower depths that floating fountains can't reach, particularly in deep lakes and ponds. Submersed aeration systems utilize a weather-protected on-shore compressor to pump air through a subsurface tube to submerged bubble diffusers. As the bubbles rise, they carry the low oxygen water from the bottom towards the surface, where it mixes with the oxygen-rich surface water and atmospheric oxygen before sinking back to the bottom. The continuous vertical mixing helps to increase dissolved oxygen concentration throughout the entire waterbody. There is a demand on the oxygen present in a waterbody due to biological processes that are occurring. Oxygen is quickly depleted at the bottom of a eutrophic or nutrient rich water body. Oxygen is absorbed at the surface, but fails to reach the bottom due to thermal stratification and lack of circulation.

Stratification occurring during the warmer months when colder, more dense water remains at the bottom of a water body while the warmer water is on the top. There is a physical barrier between these layers due to the thermal difference and the layers do not mix. A shallow pond or lake may not stratify because of the depth.

Lake turnover is a natural process that occurs in many lakes during the spring and fall seasons. During the spring turnover, the surface water, which is heated by the sun, is more buoyant than the cooler bottom water and begins to rise up. As the warm surface water rises, it pushes the cooler, denser water down, causing the lake to mix. This mixing of the water helps to reduce stratification, which is when a lake becomes divided into layers due to different temperatures and densities. By mixing the lake's water, the lake turnover helps to reduce stratification and improve the lake's water quality by increasing the amount of oxygen in the lake and decreasing the amount of pollutants and sediments. Additionally, it helps to increase the number of beneficial bacteria in the lake, which can improve the lake's water clarity.

Fountain surface aeration is a localized circulation system and is recommended for shallow lakes or ponds. Subsurface aeration is the best system for large, deep bodies of water. Using a high-quality system that is the correct type and size will keep the water clean and clear, the fish healthy, and the vegetation in balance.

<u>Benefits of lake aeration include:</u>

- Improved Water Quality –Help maintain higher oxygen levels and diffused aeration will help get oxygen to the deep water and prevent the buildup of toxic gases.
- Less Odor – Higher oxygen levels help the aerobic bacteria break down organic material in a water body. In the presence of oxygen, these bacteria are more efficient and beneficial to the health of your lake or pond.

- Reduced Nutrient Load – Aeration helps maintain the delicate balance of a healthy ecosystem in a pond or lake. When valuable oxygen is maintained at higher levels, nutrients will be broken down and used up which helps prevent possible algae mats and blooms.

- Better Fish Habitat – Diffused aeration prevents stratification to maintain an oxygen healthy habitat for fish and aquatic organisms they feed on. Using aeration to prevent ice from forming will prevent fish kills that can occur under the ice due to low oxygen levels in the winter months.

- Mosquito Control – Stagnant water is a breeding ground for mosquitos. A floating fountain or the diffused system naturally disrupts the breeding habitat necessary for mosquitos. With the risk of West Nile Virus and the other diseases mosquitos carry and transmit to people livestock and pets, aeration is as much a health concern as it is an environmental concern.

- Less Muck – Aeration may help prevent the necessity for excessive sediment removal from your pond or lake in the future by limiting the accumulation of debris and sediment that causes a layer of "muck." By promoting the natural decomposition of organic matter with oxygen-rich conditions, the ecosystem at the bottom of your pond or lake will stay more balanced.

Prospect Lake Status

ERS collected water samples from two locations at Prospect Lake; shoreline and boat launch, on March 2nd, 2022. Most values fell within the recommended range for optimal lake and fisheries management, except for particularly high Chlorophyll *a* contents (Table 1 and 2). These elevated chlorophyll *a* values indicate a high presence of algae in the water column.

TABLE 1. – Summary of water quality results from samples collected March 2nd, 2022 at the shoreline of Prospect Lake (RLR = recommended level or range for optimal lake and fisheries management).

Water Quality Parameter	Result	RLR
Temperature (°F)	48	33 - 85
pH	8	6 - 9
Ammonia nitrogen (mg/L)	0.25	< 0.5
Nitrite nitrogen (mg/L)	< 0.05	< 0.05
Alkalinity, total (as $CaCO_3$; mg/L)	200	20 – 400
Chloride (mg/L)	60	< 75
Carbon dioxide (mg/L)	No Free C	< 10
Hardness, total (as $CaCO_3$; mg/L)	180	20 - 300
Dissolved oxygen (mg/L)	18	>6
Chlorophyll *a* (mg/m^3)	**264**	< 10

TABLE 2. – Summary of water quality results from samples collected March 2nd, 2022 at the boat launch of Prospect Lake (RLR = recommended level or range for optimal lake and fisheries management).

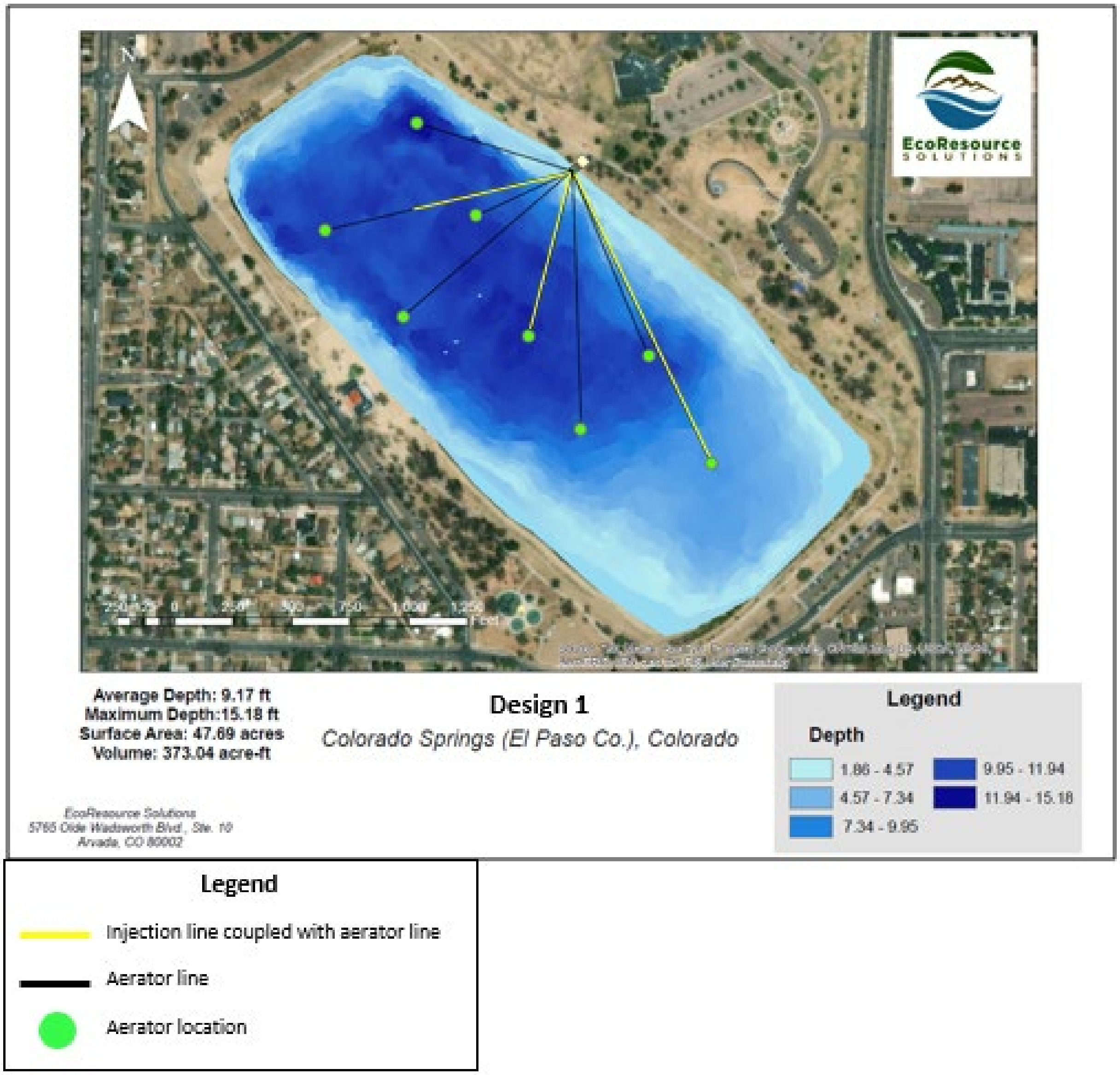
Water Quality Parameter	Result	RLR
Temperature (°F)	48	33 - 85
pH	8	6 - 9
Ammonia nitrogen (mg/L)	0.25	< 0.5
Nitrite nitrogen (mg/L)	< 0.05	< 0.05
Alkalinity, total (as $CaCO_3$; mg/L)	220	20 – 400
Chloride (mg/L)	60	< 75
Carbon dioxide (mg/L)	< 5 (1 PPM)	< 10
Hardness, total (as $CaCO_3$; mg/L)	140	20 - 300
Dissolved oxygen (mg/L)	14	>6
Chlorophyll *a* (mg/m^3)	**690**	< 10

2.0 Breakdown of Potential Lake Systems

The City of Colorado Springs has contracted EcoResource Solutions (ERS) to design an aeration system for Prospect Lake. The main objective is to implement an aeration system and injection system capable of distributing liquid treatment to the lake to combat blue green algae blooms and fish kills. Following are two potential systems; Design 1 and Design 2.

NOTE: Calculations regarding oxygenation of substrate, nutrient impacts, and other quantifiers differ greatly by lake as the systems are highly variable. These are estimations and should be regarded as loose trends as opposed to set parameters (Holmroos et al 2016).

Design 1



Design 1 consists of one 7.5-HP screw-type compressor with 8 double-disk membrane diffusers (shown in green on map). The aeration lines and diffusers are situated on the lakebed and are placed to target the deepest parts of the lake while maintaining full lake coverage. Production is approximately ½ that of Design 2 but can still be effective for aerating this size of lake.

This system results in a lake turnover rate of 0.45 days and total time to circulate one lake volume is 53.39 hours. For our model this is considered effective to ensure oxygen is circulating through the lake and anoxic conditions that promote fish kills are avoided. Full specs in appendix (pg. 12). This means that using this system, the lake will turn over 0.45 times per day (close to one full turnover every two days) and will take 53.39 hours to circulate the volume of the lake. By mixing the lake's water, the lake turnover helps to reduce stratification and improve the lake's water quality by increasing the amount of oxygen in the lake and decreasing the amount of pollutants and sediments. This lake turnover rate can be estimated to slightly reduce excess nutrient content (nitrogen and phosphorus).

The availability of dissolved oxygen (DO) is usually the first factor that limits increased carrying capacity (living organisms in the system). Using aeration as a means of providing dissolved oxygen, a system can support about 40 kg per m^3 (0.33 lb of fish per gallon) of water (Timmons 2016). For example, by increasing the DO concentration at the inlet to a production tank from 10 mg/L to 18 mg/L using aeration, and assuming a DO concentration of 6 mg/L at the discharge, the carrying capacity of the system can be increased by a factor of three. This model would have an oxygen transfer rate of 28.92 lbs of oxygen an hour, which is capable of increasing the lakes DO concentration and increasing the carrying capacity (fish populations).

Design 1 includes an injection system with lines coupled with aeration lines. The injection system will allow the city to disperse chemicals, algaecides, herbicides, bacteria, etc. to the lakebed for diffusion into the water body. The injection lines will be spread out to allow even coverage throughout the lake and target deeper lake sections. The chemicals can be added to a 275-gallon tank housed in the shoreline shed (in yellow) and switched on to quickly and efficiently disperse into the lake.

Design 1 would have no surface structures and only aeration and injection lines on the lakebed. This would classify it as a boater friendly option as there would be no obstructions for motorists and the only concern would be damaging of lines by boaters running aground in shallow areas. Design 1 contains only 8 aeration lines, all targeted to deep sections of the lake which helps to minimize potential boater impacts.

<u>Pro/Con:</u>

Pro: effective lake aeration, reduces excess nutrient content, increased lake dissolved oxygen potential, injection system compatible, boater friendly, cheaper

Con: less effective aeration, nutrient reduction, and DO potential than Design 2

<u>Cost estimate</u>

price of materials, labor costs not included

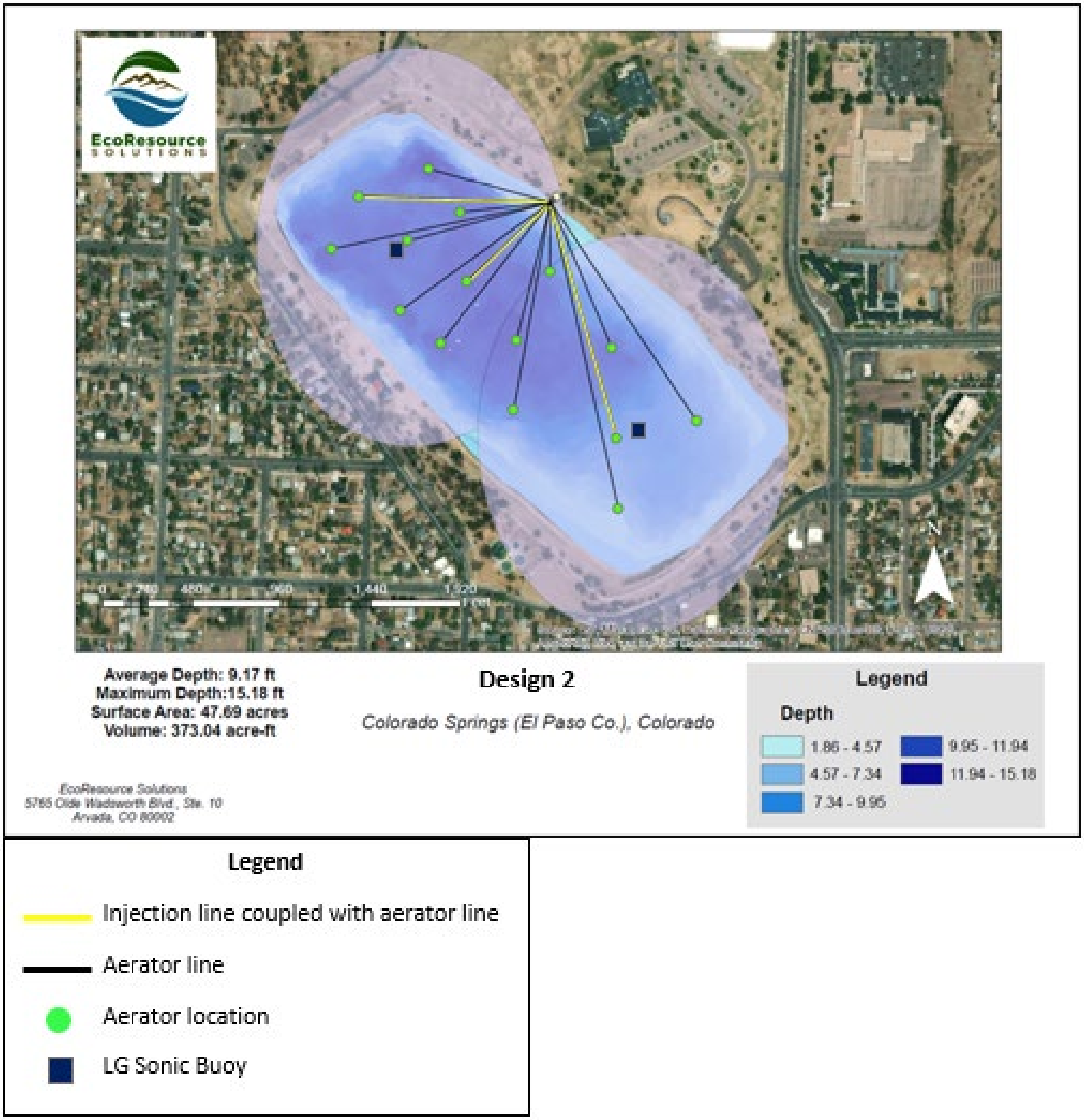
Compressor: ~$12,000

Injection system: ~$6,000

Aeration lines: ~$5,000

Total: ~$23,000

Design 2 Option



Design 2 consists of two 7.5 horsepower screw-type compressors with 15 double-disk membrane diffusers (shown in green on map). The aeration lines and diffusers are situated on the lakebed and are placed to target the deepest parts of the lake while maintaining full lake coverage. This results in a lake turnover rate of 0.84 days and total time to circulate one lake volume is 28.48 hours. For our model this is what is considered “optimal” to ensure oxygen is circulating through the lake and anoxic conditions that promote fish kills are avoided. Full specs in appendix (pg. 13). This means that using this system, the lake will turn over 0.84 times per day (close to one full turnover a day) and will take 28.48 hours to circulate the volume of the lake. By mixing the lake's water, the lake turnover helps to reduce stratification and improve the lake's water quality by increasing the amount of oxygen in the lake and decreasing the amount of pollutants and sediments. This lake turnover rate can be estimated to slightly reduce excess nutrient content (nitrogen and phosphorus).

The availability of dissolved oxygen (DO) is usually the first factor that limits increased carrying capacity (living organisms in the system). Using aeration as a means of providing dissolved oxygen, a system can support about 40 kg per m^3 (0.33 lb of fish per gallon) of water (Timmons 2016). For example, by increasing the DO concentration at the inlet to a production tank from 10 mg/L to 18 mg/L using aeration, and assuming a DO concentration of 6 mg/L at the discharge, the carrying capacity of the system can be increased by a factor of three. This model would have an oxygen transfer rate of 54.23 lbs of oxygen an hour, which is capable of increasing the lakes DO concentration and increasing the carrying capacity (fish populations).

Design 2 includes 2 in-lake LG Sonic Ultrasonic algae control units. The LG Sonic Buoys work by emitting ultrasonic wavelengths that are specified to target algae in the water. The buoy units are anchored to the lake bottom and float at the water's surface. The ultrasonic wavelengths "trap" and suspend the algae in the water column below their comfortable habitat range. The algae then becomes light limited (reduced photosynthesis capabilities) and are unable to survive. This can be an effective system in reducing the lakes elevated chlorophyll *a* levels (Table 1 and 2). This system has been used in various lakes throughout Colorado and is widely deemed successful in algae control. Prospect Lake is too large for 1-buoy units as the LG Sonic representative has suggested a 2-buoy system for adequate lake coverage. The ultrasonic wavelengths do not harm or interact with other wildlife or humans and only impact algae.

Design 2 includes an injection system with lines coupled with aeration lines. The injection system will allow the city to disperse chemicals, algaecides, herbicides, bacteria, etc. to the lakebed for diffusion into the water body. The injection lines will be spread out to allow even coverage throughout the lake and target deeper lake sections. The chemicals can be added to a 275-gallon tank housed in the shoreline shed (in yellow) and switched on to quickly and efficiently disperse into the lake.

Design 2 contains multiple surface structures; 2 LG Sonic units. These present a safety hazard for motorized boats and motorized activities, therefore there is a considerable concern for motorists. Lighted buoys can be provided to warn boaters to keep their distance. This option also provides more aeration lines, some of which are in shallower water (3-5 ft depth), which increases the potential for damage by motorists.

<u>Pro/Con:</u>

Pro: optimal lake aeration, reduces excess nutrient content, increased lake dissolved oxygen potential, injection system compatible, algae (chlorophyll *a*) control system- LG Sonic

Cons: more expensive, contains lake surface structures (boating hazard)

<u>Cost estimate</u>
price of materials, labor costs not included

Compressors: ~$24,000

Injection system: ~$6,000

Aeration lines: ~$8,500

2 LG Sonic Units: ~$115,000

Total: ~$153,500

3.0 Systems Comparison

	Design 1	**Design 2**
Lake Turnover Rate	0.45 days	**0.84 days**
Circulate Lake Volume	53.39 hours	**28.48 hours**
Oxygen Transfer Rate (impacts fish carrying capacity)	28.92 lbs/hr	**54.23 lbs/hr**
Algae Targeting (chlorophyll *a*)	None	**2 LG Sonic Buoy Units**
Cost	**Cheaper**	More expensive
Boater Friendly	**Yes**	No (2 surface structures)
Vandalism/damage risk	**Low (only lines)**	Higher (2 surface structures)
Injection System	Yes	Yes

4.0 References

Holmroos H, Horppila J, Laakso S, Niemistö J, Hietanen S. Aeration-Induced Changes in Temperature and Nitrogen Dynamics in a Dimictic Lake. J Environ Qual. 2016 Jul;45(4):1359-66.

Timmons M.B. Gas Transfer. The Conservation Funds Freshwater Institute. 2016.

Appendix

System Specs

Design 1 Aeration System Specs

EcoResource Solutions, Inc. - Lake Aeration System Design

Project: Prospect Lake, City of Colorado Springs, Colorado
Date: Feb-23

EcoResource SOLUTIONS

Lake Conditions:

Surface Area (acres)	47.69	Site Elev. (ft msl)	6087
Mean Depth (ft)	9.17	Site DO (ppm)	6.28
Max. Depth (ft)	15.18	SDI Factor	1.77
Diffuser Depth (ft)	12.00	Secchi Depth (ft)	1.87
Max. H2O Temp. (oF)	80.00	Lake Volume (MG)	142.50
Max BOD5 (mg/L)	6.50	Number of Lakes	1

System Requirements:

Required CFM	20.00
Required psi due to Total Friction Loss	7.60
Diffuser Type	OA-D
Number of Grids	8
Max. Diffuser Depth (ft)	12.00
Tubing Size (in)	0.5
Longest Tubing Run (ft)	1450
Compressor Model	IR 7.5
Number of Compressors	1
Power Supply: Phase	1
Power Supply: Volts	100-230
Power Supply: Hz	60

Aeration Production:

Compressor Efficiency (%) at Site Elevation	75.65
Max. psi Produced	87.76
Difference Between psi Produced and psi Friction Loss	80.85
Max. CFM Produced	19.9
Difference Between CFM Produced and Required CFM	-0.10
Total Flow Rate (MGD)	64.05
Lake Turnover Rate (times per day)	0.45
Hours Required to Circulate One Lake Volume	53.39
Oxygen Transfer Rate (lbs O2/hr) - Water Column	28.92
Corrected O2 Transfer Rate for Maintaining 6 ppm in Lake Bottom	1.08

Design 2 Aeration System Specs

EcoResource Solutions, Inc. - Lake Aeration System Design

EcoResource SOLUTIONS

Project: Prospect Lake, City of Colorado Springs, Colorado
Date: Jun-22

Lake Conditions:

Surface Area (acres)	47.69	Site Elev. (ft msl)	6087
Mean Depth (ft)	9.17	Site DO (ppm)	6.28
Max. Depth (ft)	15.18	SDI Factor	1.77
Diffuser Depth (ft)	12.00	Secchi Depth (ft)	1.87
Max. H2O Temp. (oF)	80.00	Lake Volume (MG)	142.50
Max BOD5 (mg/L)	6.50	Number of Lakes	1

System Requirements:

Required CFM	30.00
Required psi due to Total Friction Loss	6.27
Diffuser Type	OA-D
Number of Grids	15
Max. Diffuser Depth (ft)	12.00
Tubing Size (in)	0.5
Longest Tubing Run (ft)	1450
Compressor Model	IR 7.5
Number of Compressors	2
Power Supply: Phase	1
Power Supply: Volts	100-230
Power Supply: Hz	60

Aeration Production:

Compressor Efficiency (%) at Site Elevation	75.65
Max. psi Produced	87.76
Difference Between psi Produced and psi Friction Loss	82.06
Max. CFM Produced	39.8
Difference Between CFM Produced and Required CFM	9.80
Total Flow Rate (MGD)	120.10
Lake Turnover Rate (times per day)	0.84
Hours Required to Circulate One Lake Volume	28.48
Oxygen Transfer Rate (lbs O2/hr) - Water Column	54.23
Corrected O2 Transfer Rate for Maintaining 6 ppm in Lake Bottom	2.02

Itemization

Items required for system components (or equivalent)

Design 1 Itemization

Item	Quantity
UP6-7.5 TAS 125 PSI Rotary Screw Air Compressor W/Dryer	1
230/1/60 Open Drip Proof Motor	1
80 Gallon Receiver	1
Pre-Filter	1
Standard Crating	1
230/1/60 Starter	1
Hourmeter	1
Electronic Drain Valve	1
Dryer	1
Start-Up Kit (Ultra Coolant)	1
Power Outage Restart Option	1
Ultra Coolant	1
Double disk membrane diffusers	8
275 gallon low profile rectangle	1
275 gallon low profile tank with elevated pump and aluminim frame	1
Strap kit	1
Internal tank dual jet agitation assembly	1
Pumptec PN 81524-X3/m930	1
Check valve	1
1/2' stainless steel hose barb	1
Electrical components to wire in one engine/hose reel, #8 wire, fuse, circuit breaker, crimp on wire ends	1
stainless steel coupling 1/2"	1
Battery 27DCGC	1
Pumptec PN 70174-Bypass regulator	1
Catch bucket	1
Stop valve	12
1/2" copper pipe connectors/coupling	20
1/2" copper pipe tee connect	8
1/2" x 10' stainless steel braided supply line	2
1/2" x 10' copper pipe	6
1-1/2" galvanized pipe holder	20
1/2" 90 degree copper slip elbow fitting	10
Blue stripe 1/2" X 300' 600 PSI braided hose with liner	34
1/2" barbed tubing connector	8
Miscellaneous screws	NA

Design 2 Itemization

Item	Quantity
UP6-7.5 TAS 125 PSI Rotary Screw Air Compressor W/Dryer	2
230/1/60 Open Drip Proof Motor	2
80 Gallon Receiver	2
Pre-Filter	2
Standard Crating	2
230/1/60 Starter	2
Hourmeter	2
Electronic Drain Valve	2
Dryer	2
Start-Up Kit (Ultra Coolant)	2
Power Outage Restart Option	2
Ultra Coolant	2
Double disk membrane diffusors	15
275 gallon low profile rectangle	1
275 gallon low profile tank with elevated pump and aluminim frame	1
Strap kit	1
Internal tank dual jet agitation assembly	1
Pumptec PN 81524-X3/m930	1
Check valve	1
1/2" stainless steel hose barb	1
Electrical components to wire in one engine/hose reel, #8 wire, fuse, circuit breaker, crimp on wire ends	1
stainless steel coupling 1/2"	5
Battery 27DCGC	1
Pumptec PN 70174-Bypass regulator	1
Catch bucket	1
Stop valve	20
1/2" copper pipe connectors/coupling	10
1/2" copper pipe tee connect	10
1/2" x 10' stainless steel braided supply line	3
1/2" x 10' copper pipe	10
1-1/2" galvanized pipe holder	30
1/2" 90 degree copper slip elbow fitting	20
Blue stripe 1/2" X 300' 600 PSI braided hose with liner	55
1/2" barbed tubing connector	15
Miscellaneous screws	NA
MPC Buoy system (componenets supplied)	2
Lighted buoy	8