DEPARTMENT OF MECHANICAL ENGINEERING

Algae Control Device (G1)

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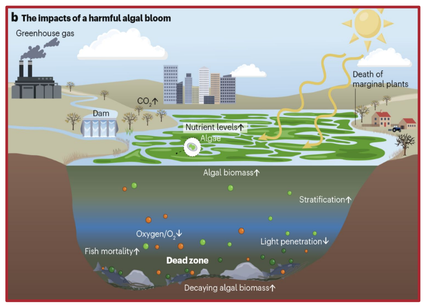
Motivation, Goal, Impact

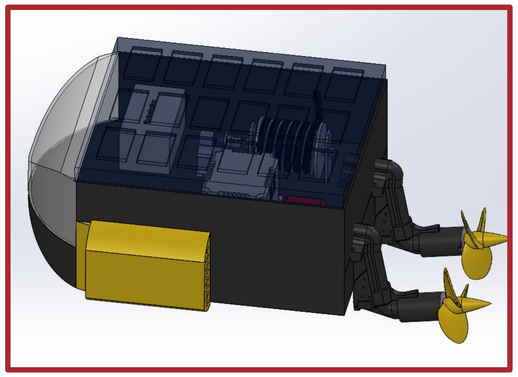
- Harmful Algae Blooms **damage ecosystems** and threaten human health; our solution **protects** aquatic environments.
- **Aerate** pond water **to boost** oxygen levels and **remove surface algae** to restore pond health.



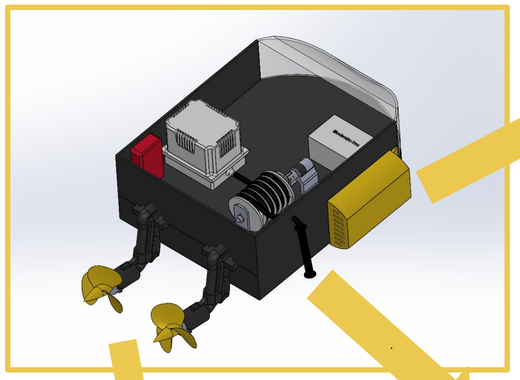
Requirements

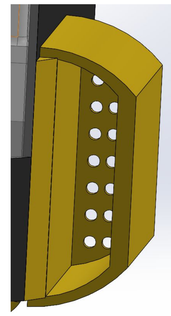
- Identify and **aerate zones** with **low oxygen levels (<2mg/L)**.
- Autonomously relocate to different algae hotspots within the pond.
- **Remove surface algae** at a rate of 5 m^2 per minute to improve water quality.
- **Limit** the amount of algae growth to acceptable turbidity levels of 40 NTU
- Communicate real time updates to end user.
- Be able to circumnavigate the pond in 10 minutes

Final Design

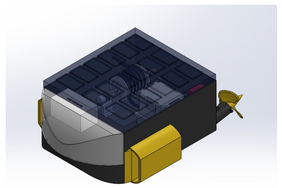


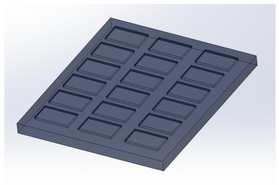
Dimensions: 30in (L) x 28in (W) x 13in (H)



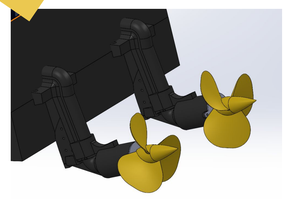


Surface Algae Collection

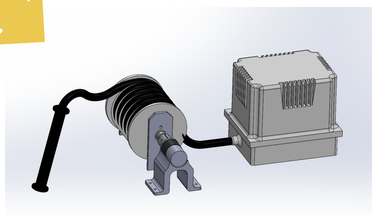




Solar Panel



Propulsion System



Aeration System

Design Calculations & Decisions

Performance Calculations

$Representative\ Target\ Pond\ Radius \approx 36\ m$
$Pond\ Area = 4030\ m^2 \sim 1\ acre$

$Max\ Aeration\ Volume = Operating\ Depth * Aeration\ Area$

$Target\ Volume\ per\ Cycle = 15,000\ gallons = 56.78\ m^3$
$Target\ Depth: 15\ ft = 4.572\ m$

$Aeration\ Area = 12.43\ m^2$
$Aeration\ Radius \approx 2\ m$

$Pond\ Circumference = 2\pi R = 2(\pi)(35.82\ m) = 225\ m$
$Target\ Travel\ Time = 600s\ (Circumnavigate\ the\ Pond)$

$Average\ Velocity = Distance / Time = 225\ m / 600s = 0.375\ m/s$
$Average\ Operating\ Velocity = 0.375\ m/s$

Propulsion System Design

$F_{thrust} - F_{drag} = +ma$
$with\ \ a = 0\ m/s^2\ (Constant\ Velocity)\ \ or\ a = 2\ m/s^2\ (Maximum\ Acceleration)$

$F_{drag} = \frac{1}{2}\rho_{water} C_d A_{frontal} v^2 \Rightarrow \frac{1}{2}(1000\ kg/m^3)(1.1)(0.1063\ m^2)(0.375\ m/s)^2 = 8.22\ N$

$Case\ 1\ (a = 0\ m/s^2)\text{:}\ \ F_{thrust} = 8.22\ N$

$Case\ 2\ (a = 2\ m/s^2)$

$F_{thrust} = F_{drag} + ma \Rightarrow 8.22\ N + (20\ kg)(2) \Rightarrow 48.22\ N$

Motor Needed with Thrust of 48.22 N

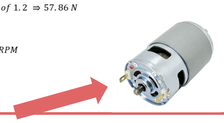
Estimating Required Power:

$P = \frac{F_{thrust} * v}{\eta}$
where $\eta = Propeller\ Efficiency = 0.5$
$v = 0.375\ m/s$
$F_{thrust} = 48.22\ N\ *\ Design\ Factor\ of\ 1.2 \Rightarrow 57.86\ N$

$P = 43.4\ W$
$Motor\ optimal\ speed = \Omega = 1600\ RPM$

$P = T * \omega$

Torque Required 0.26 N-m



Buoyancy Calculations (Stationery Position: During Oxygenation)

Using Archimedes' Principle:

$W_{boat} = m_{boat} g = (20\ kg)(9.81\ m/s^2) = 196.2\ N$
$F_b = \rho_{Water} V_{Submerged} g$
$V_{Submerged} = V_{Rectangular\ prism} + V_{quarter\ cylindrical\ circle} = 0.04467\ m^3$
$F_b = (1000\ kg/m^3)(0.04467\ m^3)(9.81\ m/s^2) = 438.2\ N$

$F_b > W_{boat} \Rightarrow Therefore\ Boat\ Will\ Float$

Aeration Calculations

$Aerating\ at\ a\ depth\ of\ 15ft$
$d = 15ft,\ r = 35.82m,\ Total\ Area = 4030m^2$
$Effective\ Area = 672m^2\ (Assume\ that\ 1/6th\ area\ Algae)$
$227g\ of\ O_2\ to\ be\ added\ to\ increase\ DO\ by\ 4mg/L\ over\ 15000\ gallons$
$Aerator\ Specifications$
$Volume_{Aerator\ Rating} = 15000\ gallons = 56.78m^3$
$Area_{Aerate} = 56.78/4.572 = 12.42m^2$
$Q_{Air} = 7.1ft^3/min;\ Q_{O_2} = 1.876moles/min = 60.032grams/min$

Power Requirement

$Estimating\ total\ Wattage = W_{tot}$

$V = I * R$
$W = V * I$
$W_{max\ ardino} = 5 * 2.4 = 12\ W$
$Given\ 40\ W\ aeration$
$W_{motor} = 100\ W * 2 = 200\ W$
$8.3\ A\ to\ 4.2\ A$

$effective\ energy\ generated: 60 - 80\ percent$
$60\ to\ 80\ W$

$Total\ power\ needed:$
$12 + 200 + 40\ W = 252\ W$
$70\%\ effectiveness\ assumption$
$252 / 0.7 = 360\ Wh$

$Effective\ sun\ is\ about\ 4 - 5\ hrs$
$360\ Wh/4 = 90\ W$

$90/50\ is\ 1.8\ scale\ up$

$Depth\ of\ discharge: 252\ Wh$
$80\%\ for\ lithium$
$252/0.8 = 315\ Wh$

$315/12V = 26.25\ Ah$

$12\ V\ at\ 65Ah\ source\ for\ a\ 1\ day\ backup\ needed$

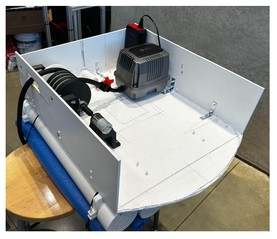
Fine Pore Diffuser

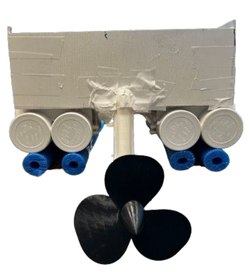
$D = 3cm,\ height = 7.62cm,\ Area_{Diffuser} = \Pi * D * h = 7181.68mm^2$
$D_{Pores} = 80\ microns,\ Area_{Pores} = \Pi * D^2_{Pores}/4 = 0.005026mm^2$
$No.\ of\ Pores = Area_{Diffuser}/Area_{Pores} = 1428906\ pores$
$Q_{Pores} = (7.1/4)/1428906 = 1.242 * 10^{-6} ft^3/min,\ Size\ of\ bubble = 2mm,\ V_{bubble} = 4.19mm^3$
$N_{Bubbles} = Q_{Pores}/V_{bubbles} = 8.394\ bubbles/min/pore = 0.1398\ bubbles/sec/min \approx 200,000\ bubbles/sec.$
$Area_{bubbles} = 2511977.33mm^2/sec,\ Lifetime_{bubble} = 15ft/0.82ft/sec = 18.29sec$

A=45.94m^2 of bubbles/diffuser at any given instant in time
Total Area of Bubbles=183.78m^2.

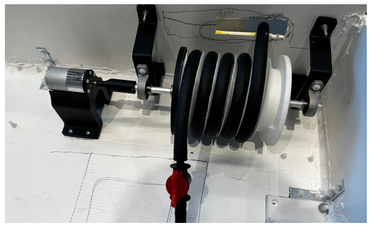
Assuming 25 − 30% efficiency we would have to aerate for 75 − 180 mins.

Prototype & Test Results



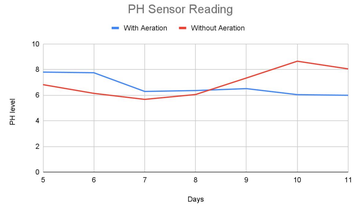


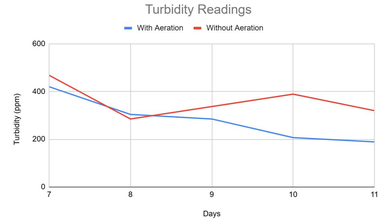
Housing

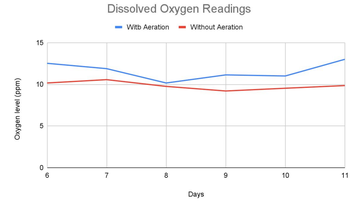


Spool Device

Aeration Device







Tank 1			Tank 2		
ph	TDS(ppm)	Oxygen(ppm)	ph	TDS(ppm)	oxygen
7.5	320	10.96	7.8	337	12.11
6.99	373	11.6	7.75	389	11.95
6.38	426	12.5	6.29	462	11.65
6.45	430	11.96	6.36	413	11.15
6.82	437	11.9	6.51	483	12.01
6.14	542	12.52	6.04	533	10.16
5.67	420	11.88	5.99	468	10.56
6.05	304	10.16	6.53	285	9.75
7.34	285	11.13	7.21	337	9.2
8.65	207	11	6.44	389	9.53
8.05	189	13	5.83	320	9.85

On Day 8, Aeration system was deployed

- PH results shows regain in stability to original conditions starting 7.5-7.8
- Dissolved Oxygen is more present after day 8 deployment
- Turbidity Reading show decrease in concentration of algae from the sensor