Sidewall-Box Airlift Pump Provides Large Flows for Aeration, CO_2 Stripping, and Water Rotation in Dual-Drain Circular Tanks

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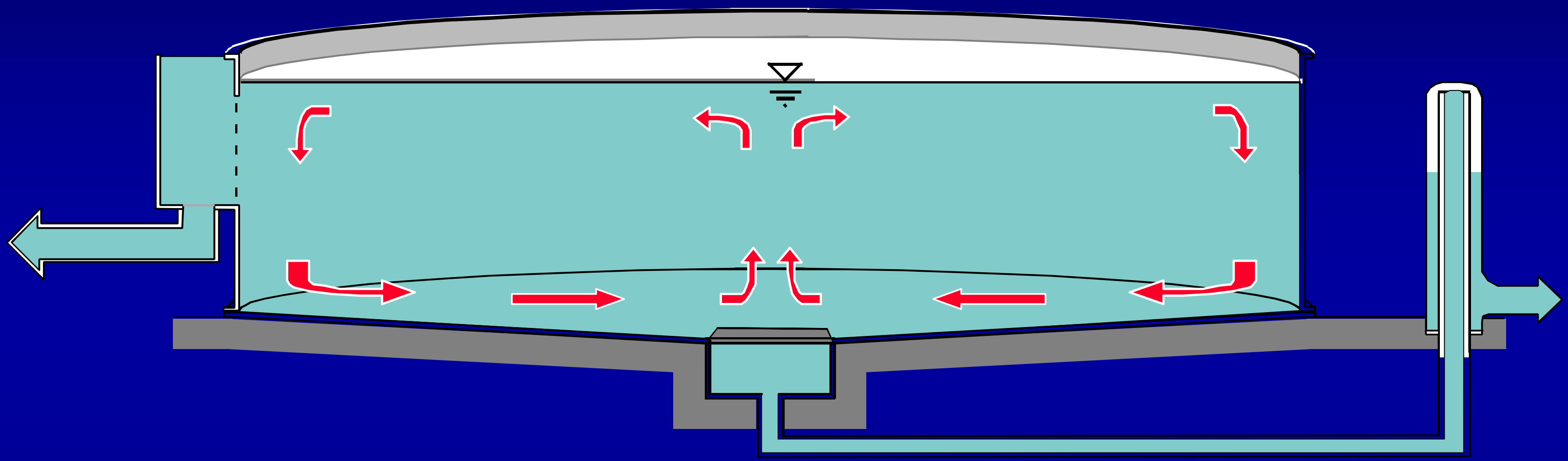
Objectives

- Develop a simplified partial water reuse system that relies on a sidewall-box airlift pump
  - ✓ reduce variable and fixed costs
  - ✓ simple system
  - ✓ does not compromise water quality

Introduction – Aeration Options

- Diffused aeration in circular tanks interferes with:
  - ✓ hydrodynamics of water rotation
  - ✓ speed and efficiency of solids fractionation to the bottom-center drain

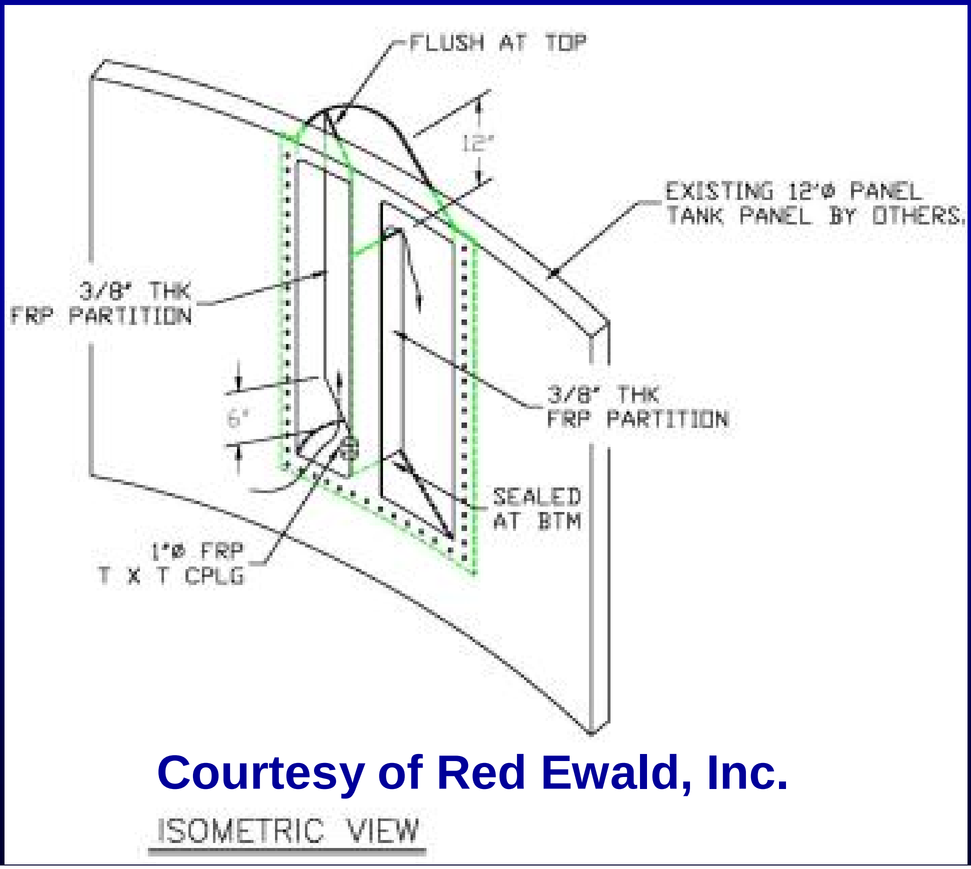
Circular Tanks: Radial Flow



- Primary rotating flow creates secondary radial flow:
  - ✓ transports settleable solids to bottom center
  - ✓ creates self-cleaning tank
  - ✓ aeration breaks apart fecal matter and interferes w/ hydrodynamics

Methods: Sidewall Box Airlift

- 1st Version used a 30 cm (12 inch) wide weir wall
  - ✓ 180 cm^2 (0.196 ft^2) plan area in airlift chamber
  - ✓ Three snap-cap diffusers (Aquatic-Eco Systems)



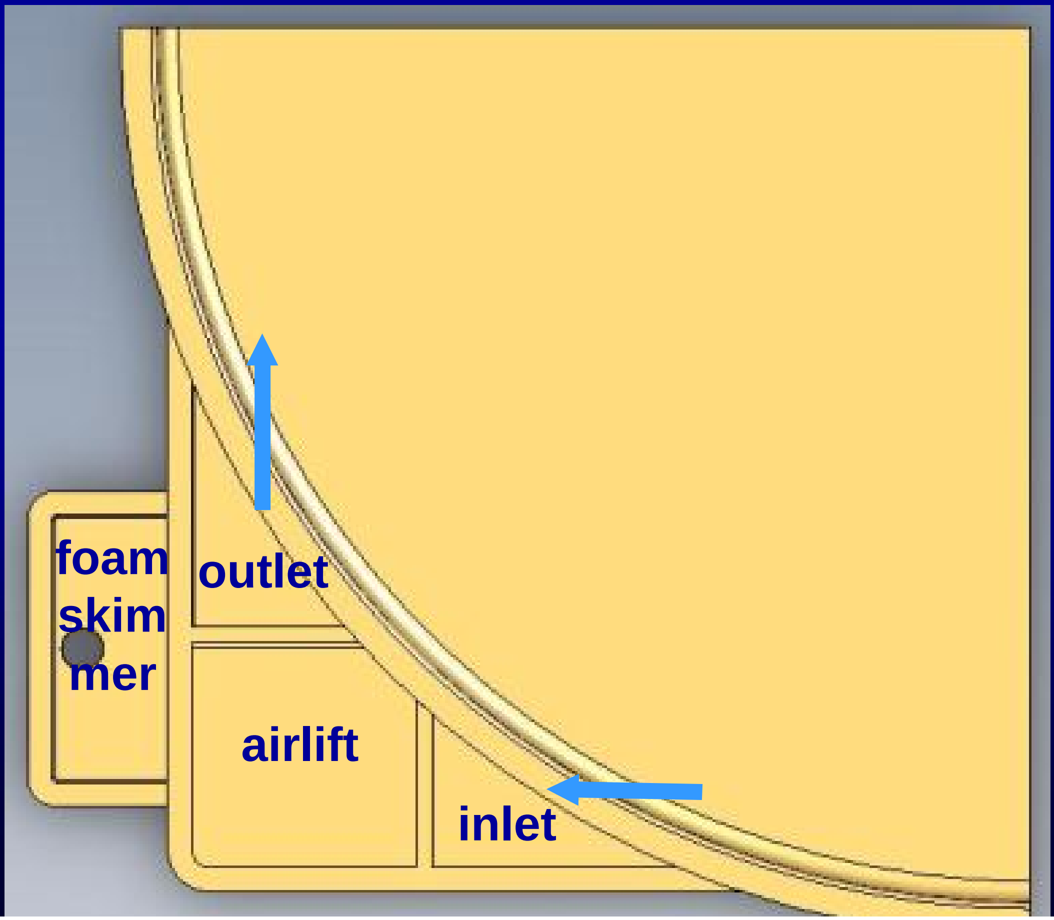
Courtesy of Red Ewald, Inc.

Methods: Sidewall Box Airlift

- 1st Version used a 30 cm (12 inch) wide weir wall

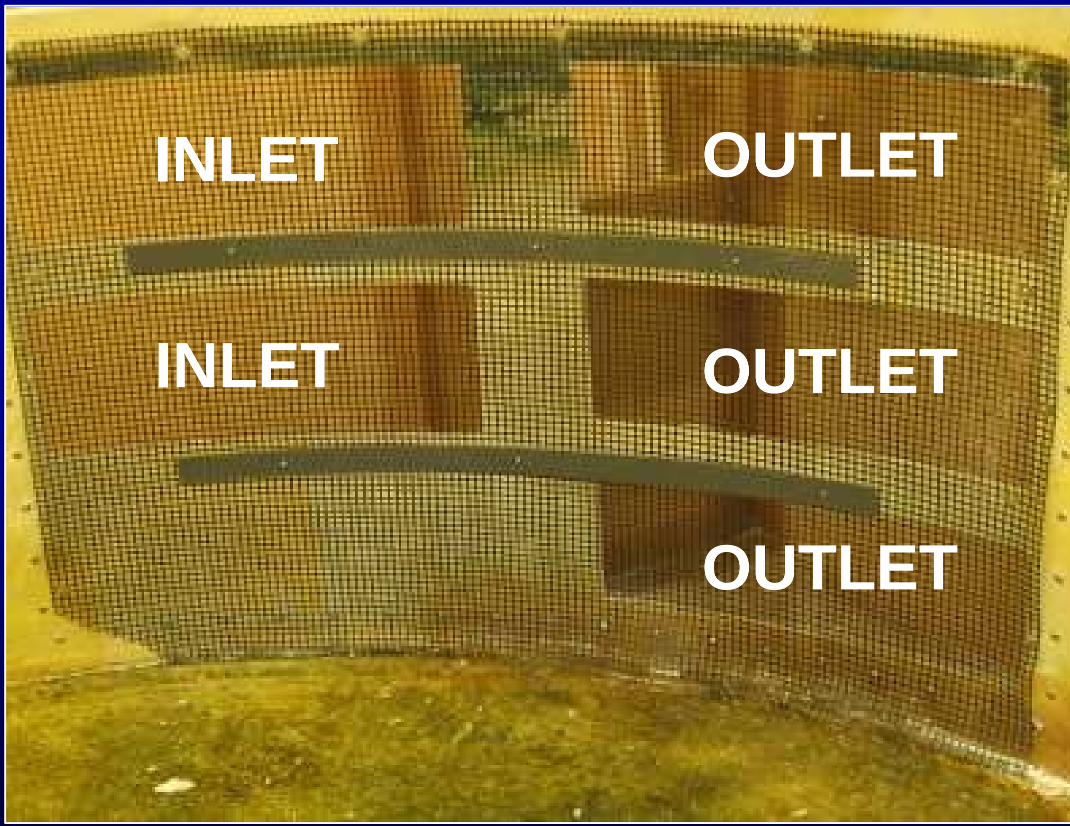
Methods: Sidewall Box Airlift

- 2nd Version used a 46 cm (18 inch) wide weir wall
  - ✓ 2060 cm^2 (2.25 ft^2) plan area = 10-times more airlift area
  - ✓ diffuser grid w/ 1.2 m of Aero-Tube Tubing (Colorite Plastics)



Methods: Sidewall Box Airlift

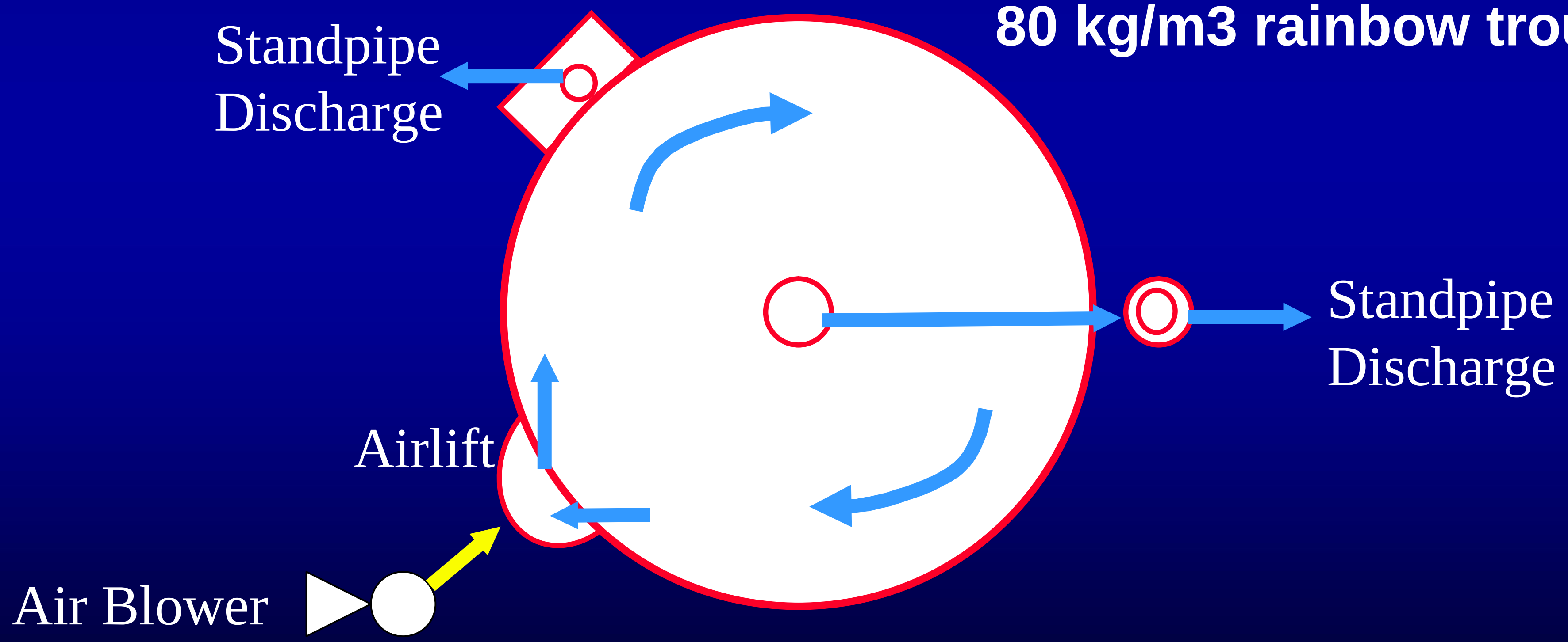
- 2nd Version used a 46 cm (18 inch) wide weir wall



Methods: Sidewall Box Airlift

- Process flow diagram

11.5 m^3 culture tank
(3.66 m dia x 1.22 m deep)
80 kg/m3 rainbow trout



Methods: Regenerative Blowers

- 1st Airlift: 0.25 KW (1/3-HP) blower
  - Model S21, Aquatic-Eco Systems, Boca Raton, Florida
- 2nd Airlift: 0.38 KW (1/2-HP) blower
  - Model S31, Aquatic-Eco Systems

Results: Sidewall Box Airlift

- Water Flow, Lift, and Upwelling Velocity in Airlift, plus Tank HRT

	1st Version Airlift (SNAP-CAPs)	2nd Version Airlift (AERO-TUBE)
Water Lift, cm	**5.1** (2 inch)	**3.8** (1.5 inch)
Water Flow Rate, m^3/min	**1.7** (440 gpm)	**1.9** (500 gpm)
Water Flow per unit energy input, m^3/min per kW	**4.4**	**3.0**
Tank HRT, min	**7**	**6**
Upwelling Velocity in Airlift, m/s	**1.52** (5.0 ft/s)	**0.15** (0.5 ft/s)

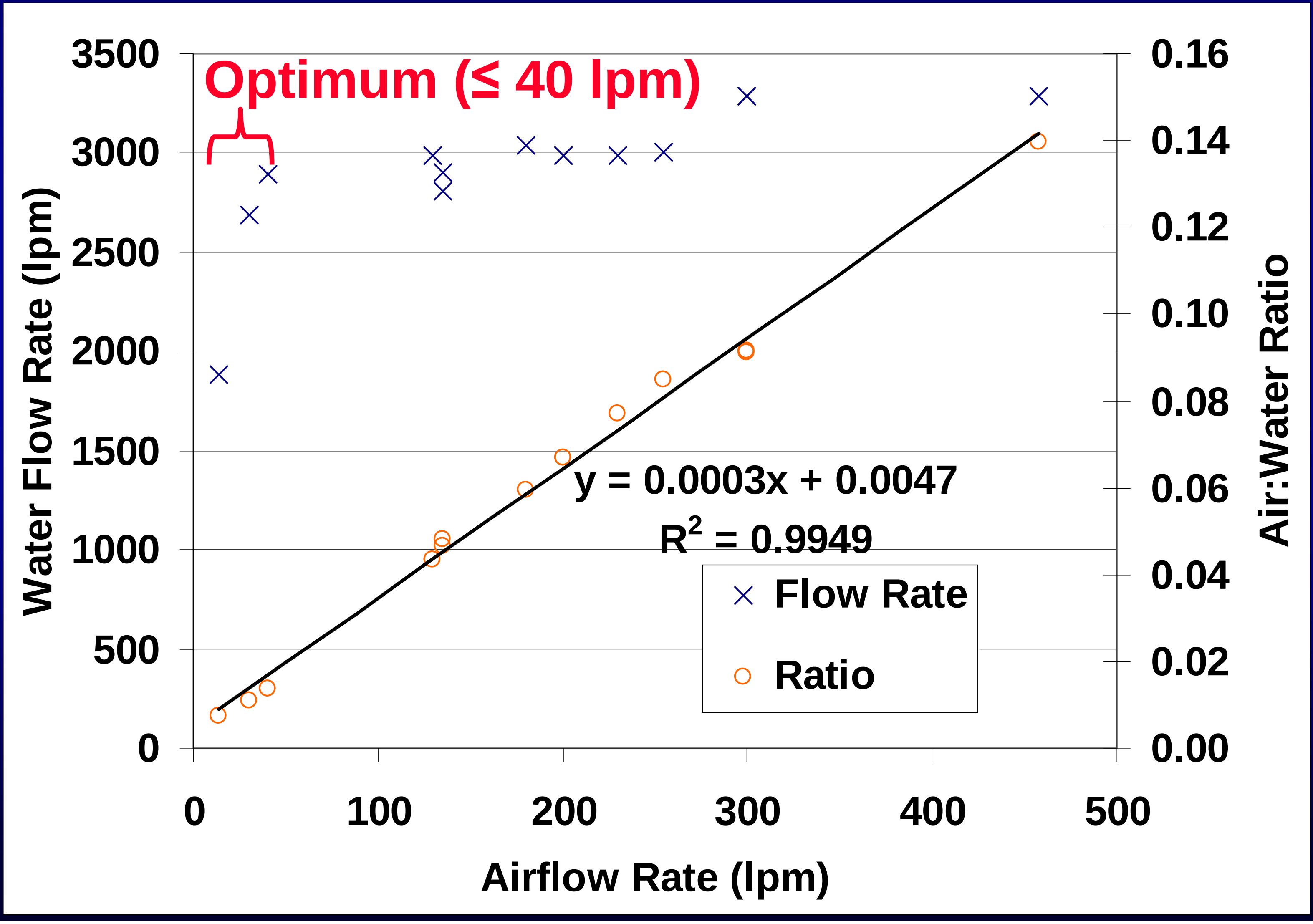
Results: Sidewall Box Airlift

- Air Flow & Pressure, Pressure Drop through Diffusers, Air:Water (vol:vol), & Line Power Req.

	1st Version Airlift (SNAP-CAPs)	2nd Version Airlift (AERO-TUBE)
Air Flow, standard L/min	96	< 40
Air Pressure, m H_2O head	1.01	1.25
Air Pressure Drop through Piping & Diffuser, m H_2O	0.15	0.315
Air:Water, vol:vol	0.06	< 0.02
Line Power Req., kW	0.39	0.64

Results: Sidewall Box Airlift

- 2^{nd} Version Airlift (Aero-Tube diffusers)



Results: Sidewall Box Airlift

- 2nd Version Airlift (Aero-Tube diffusers)
- Water flow was maximized (2900 L/min) with the least air input at:
  - ✓ Air flow rate ≤ 40 L/min (1.4 cfm)
  - ✓ Air:Water ≤ 0.015 (vol:vol)
  - ✓ Airlift upwelling water velocity ≤ 0.23 m/s (0.76 ft/s)
  - ✓ **Water Flow per unit energy input**
    - 3.0 m^3/min per kW line power
    - **Note – this may be much lower with larger blower…**

Results: Sidewall Box Airlift

- Change in dissolved O_2 & CO_2 across airlift @ tank dissolved O_2 of 7.0 mg/L and **@ 13ºC**

	1st Version Airlift (SNAP-CAPS)	2nd Version Airlift (AERO-TUBE)
O_2 increase each pass, mg/L	0.45	0.99
CO_2 decrease each pass, mg/L	1.6	2.0

Results: Sidewall Box Airlift

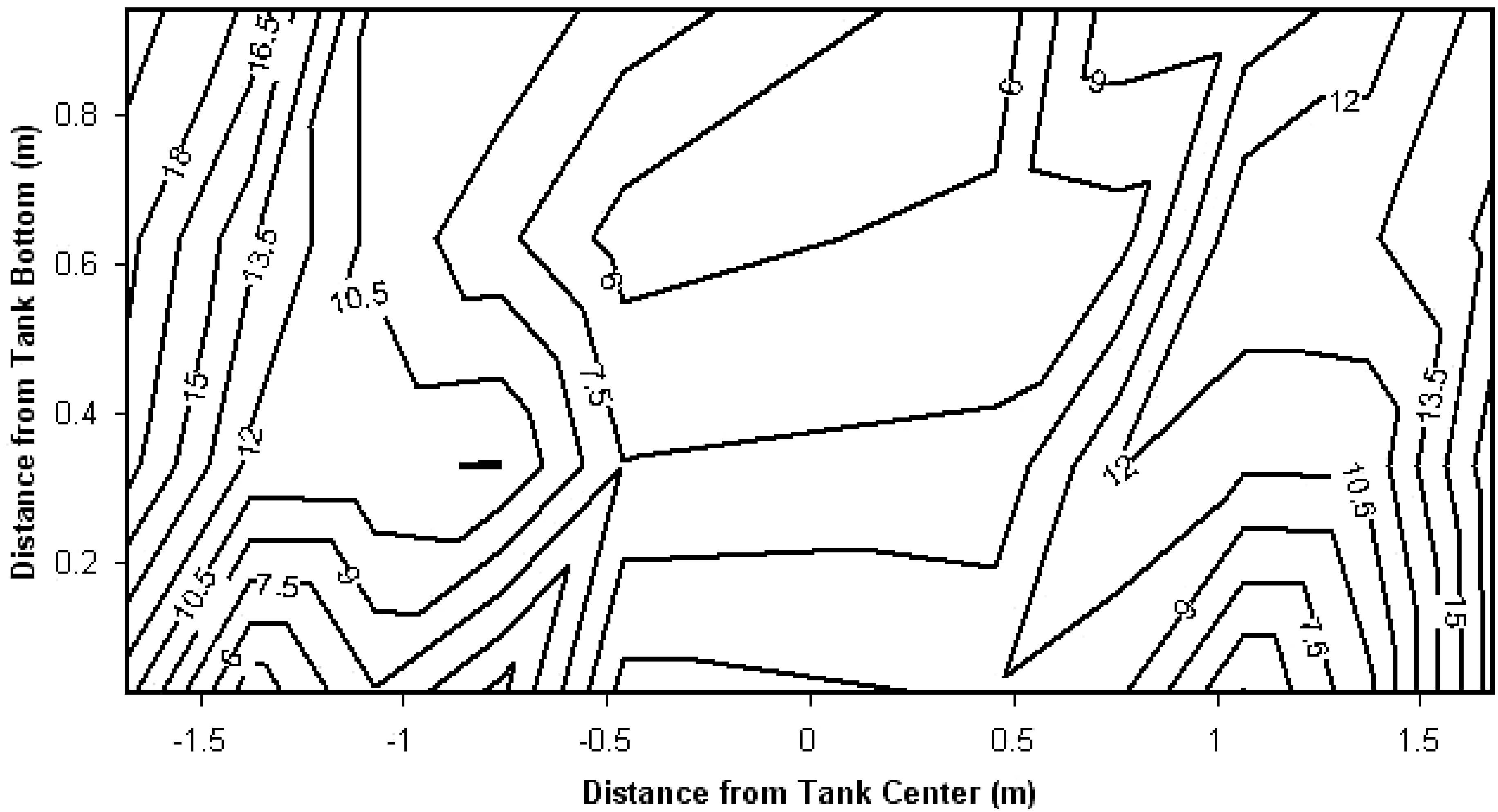
- Estimated Daily O_2 Supply, Aerator Efficiency, Carrying Capacity, & %BW/day Feed supported by airlift.

	1st Version Airlift	2nd Version Airlift
Daily O_2 supplied*, kg/d	**1.1**	**2.7**
Aerator Efficiency*, kg O2/kW-hr	**0.12**	**0.18**
Carrying capacity of airlift*, kg feed per day	**3.0**	**7.7**
% BW/day that could be fed @ 80 kg/m^3 density*	**0.33**	**0.84**

***tests conducted with dissolved O_2 inlet of 7.0 mg/L @ 13ºC**

Results: Sidewall Box Airlift

- High water flows through airlift adds impulse force to rotate tank



Circular Tanks: Optimum Velocity

- Optimum swimming velocity
  = (0.5 to 2.0) x (fish body length)/second

- Velocities in a ‘donut-shaped’ region about tank center are reduced:
  - ✓ allows fish to select a variety of swimming speeds

Results: TSS Concentration

- TSS concentrations in tank averaged 1.0 mg/L
  - ✓ do not appear to be elevated by operation of airlift

Discussion

- Comparison of fixed and variable costs of the sidewall airlift box versus a 1-HP pump (380 L/min) to aerator & oxygenator system
  - ✓ each to supply 2.7 kg O_2/day

	1-HP Pump to an Aerator & Oxygenator	2nd Version Airlift (AERO-TUBE)
Variable Costs **kW-hr/yr** **$Elect/yr (@$0.06/kW-hr)** **$O2 feed gas/yr** (assuming 1.35 kg O2/day)	**11,800** **$708** **$108**	**5,600** **$336** **$0**
Fixed Costs, $	**$8000**	**$2200**
Footprint	**larger**	**smaller**

Conclusions

- Sidewall box airlift creates simple partial-reuse system
  - ✓ Optimum conditions in test system may be:
    - Aeration via grid of diffuser hose
    - Air:Water $\leq$ 0.015 (vol:vol)
    - Airlift upwelling water velocity $\leq$ 0.23 m/s (0.76 ft/s)
  - ✓ Huge flows are created with modest energy
    - 3.0 m^3/min per kW line power with diffuser hose
    - **Note – this may be much lower with larger blower…**

Conclusions

- Sidewall box airlift creates simple partial-reuse system
  - ✓ Airlift rapidly exchanges the culture tank volume (6 min HRT)
  - ✓ Adds 1 mg/L dissolved O_2 and strips 2 mg/L CO_2 each pass
  - ✓ Rapid tank flushing adds impulse force to rotate tank
  - ✓ Tank operates on dual-drain principle & solids fractionate to bottom center drain – MAINTAINS WATER QUALITY

Conclusions

- Sidewall box airlift creates simple partial-reuse system
  - Avoids more expensive & complex
    - centrifugal pumps,
    - large dia pipe runs,
    - stripping columns, &
    - oxygenation processes

Acknowledgements

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- All experimental protocols involving live animals were in compliance with Animal Welfare Act (9CFR) and have been approved by the Freshwater Institute Animal Care and Use Committee.