2013 Light Green Machine Institute Conference

INNOVATIVE AERATION TECHNOLOGIES THAT MULTI-TASK AND SAVE ENERGY

Marc Moseley - Manager, Global Pulp & Paper Group

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PHILADELPHIA MIXING SOLUTIONS

- To varying degrees, all integrated pulp and paper mills must treat their waste water. For those that use mechanically generated oxygen from traditional aeration technologies, there are inherent processing in-efficiencies and the cost of the required energy can be quite high.
- Today there are now available, new equipment/impeller design technologies that provide multiple processing functionalities while using up to 50% less energy.

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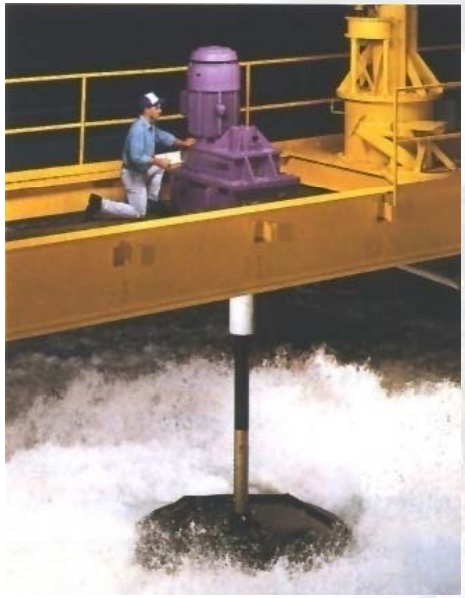
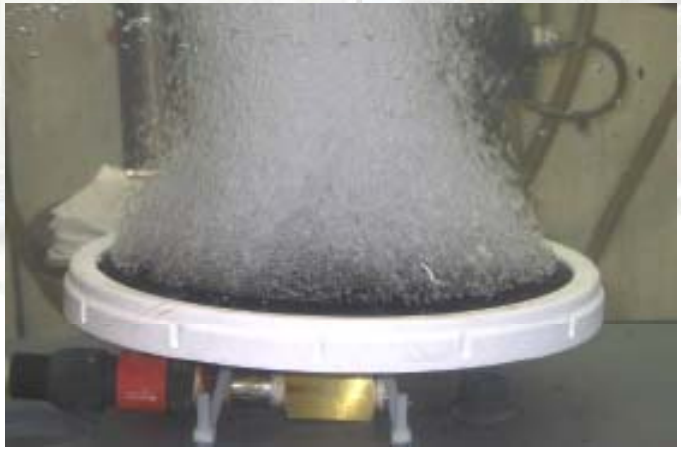
General Types of Aeration for ASB's



LSSA
Low Speed Surface Aerator

Course / Fine Bubble Diffusion



High Speed Vertical
"Donut" Aerator

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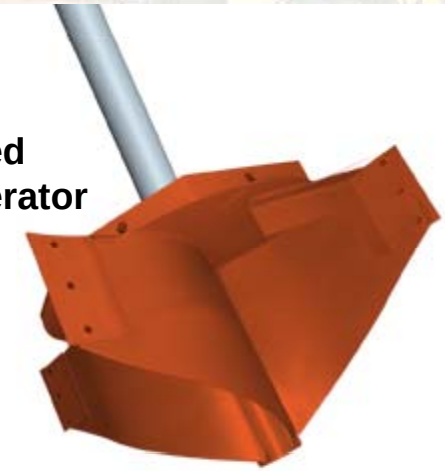
Modified Low Speed Surface Aerator

Advantages:

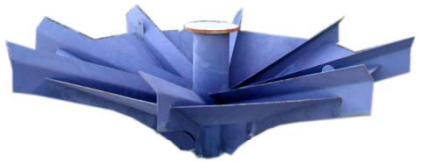
- Improves effluent quality
- Ensures biological components receive required oxygen to treat bio-solids
- Operates effectively over a large range of liquid level variations
- Enhances mixing due to the higher tangential component of velocity
- Save on power consumption and treat the same amount of wastewater
- Biologically treat move wastewater using the same power consumption

Modified Surface Aerator



Traditional Design

Traditional Design



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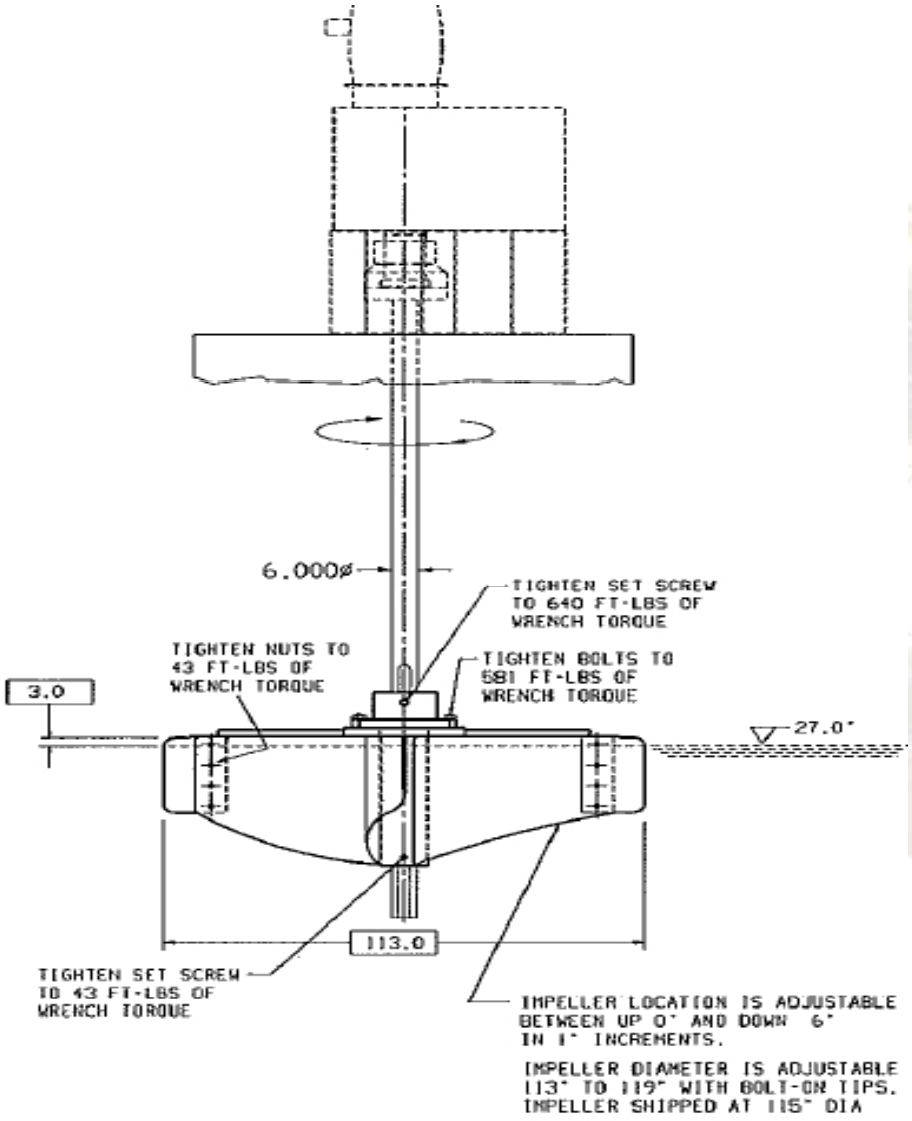
Modified Low Speed Surface Aerator



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Modified Low Speed Surface Aerator

PMSL's Approach to Surface Aeration…

Clean Water Testing

The modified surface aerator and several competitors' surface aerator impellers were run individually in a clean water tank and dissolved oxygen was measured.

The indoor basin in which the aerator impellers were tested is 50' x 60' with four support columns to simulate field conditions and a total capacity of 750,000 gallons.

Videos\Talon Testing.MPG

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Modified Low Speed Surface Aerator

Test Protocol:

Testing measurements and analysis were performed following ASCE guidelines for clean water aeration testing.

- Maximum 10 test runs on each impeller
- Various emergence levels
- Two speeds (30 and 45 horsepower)
- Measurements made with equipment running in test basin
- Measurements taken in four location at four depths at each location

Analysis:

Non-linear regression method used for date analysis

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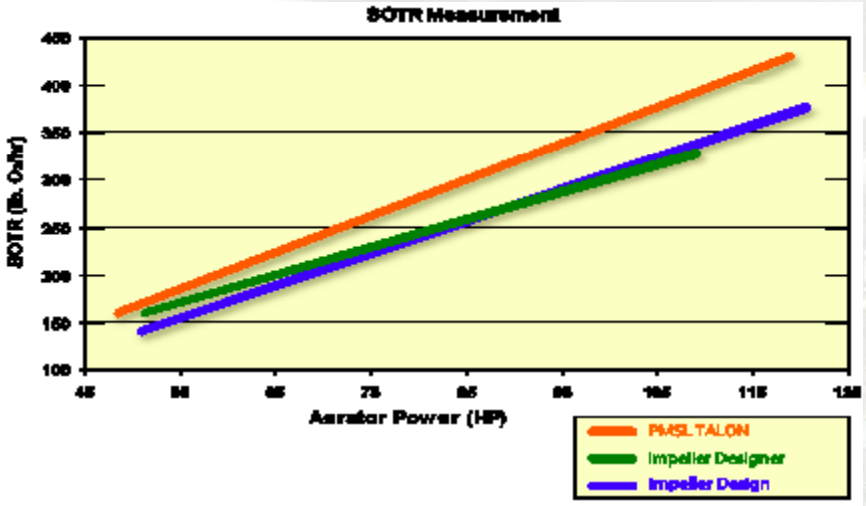
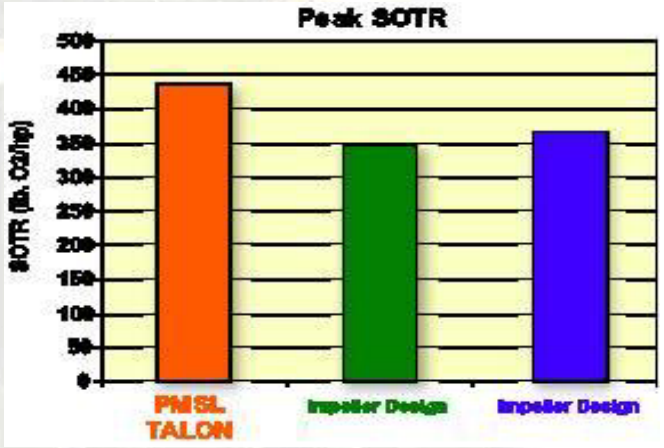
Modified Low Speed Surface Aerator



Data plotted includes a minimum of ten test runs at various emergence levels and two speeds (30 and 46 RPM.) PMSL maintains transfer efficiency over a range of speeds.



In all ranges, Modified Surface Impeller exceeds performance of impeller designs.

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Modified Low Speed Surface Aerator

Field Installation

Retrofitted modified surface aerator impellers in a aeration ditch in Orange County, Florida, providing the opportunity to conduct a side by side comparison with surface aerator impellers of traditional design.

Eastern Water Reclamation Facility (EWRF), Orange County, Florida began operating in 1984 and has a current treatment capacity of 19 million gallons per day.

Test Protocol:

With all aerators operating in separate ditches, periodic measurements were taken in each ditch over four days of data collection:

- Horsepower (based on continuous watt meter readings)
- Total Flow (head over corresponding weirs in each ditch)
- Total suspended solids (TSS) and volatile suspended solids (VSS)
- Dissolved oxygen
- Ammonia levels
- Return Activated Sludge (RAS) rates
- Influent Flow – total plant flow

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Modified Low Speed Surface Aerator

Analysis:

1. Total flow, RAS and weir measurements were used to calculate “load” distribution to the ditches
2. TSS and VSS data confirmed that all ditches were essentially operating in identical modes to F:M and SRT etc.
3. Load and power comparisons were used to derive preliminary transfer efficiency results
4. Process modeling (biological simulations) was employed to take the DE and ammonia levels into account to derive final comparative SAE

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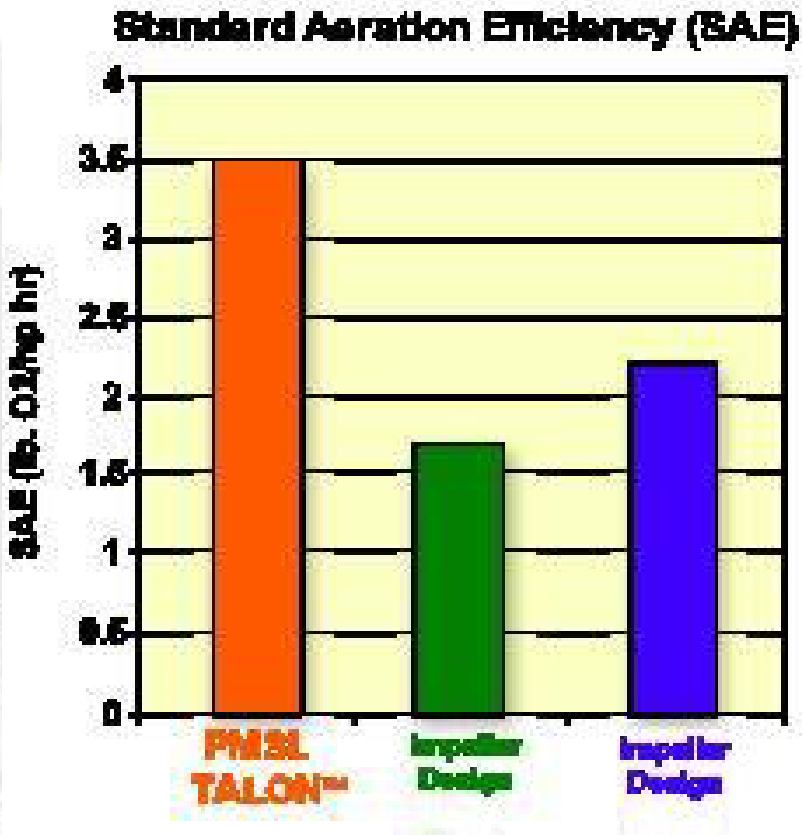
Modified Low Speed Surface Aerator

Employing process modeling (biological simulations) to derive a comparative SAE, the Modified Surface Aerator is up to 32% more efficient than Traditional A Impeller design and in addition the Modified Impeller performed well over 100% more efficiently than the Traditional B Impeller design.



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Types: High Speed Mechanical Surface Aerator

Videos\Vertical Aerator.wmv

- Most common form of high speed mechanical aeration “donut”. Effective technology for its day
- Relatively low oxygen transfer efficiencies (> 2 lbs. O_2 / Hp. Hr.) versus newer technologies
- Depends on localized aerosol effect for O_2 transfer contributing to odor, foam and potential icing
- Initial cost is low but ongoing maintenance and energy costs are higher versus newer technologies
- Given the floating design, installation is inexpensive and offers flexibility when additional aeration is required.
- Mixing is generally poor leading to settling, deposition development and declining process efficiency

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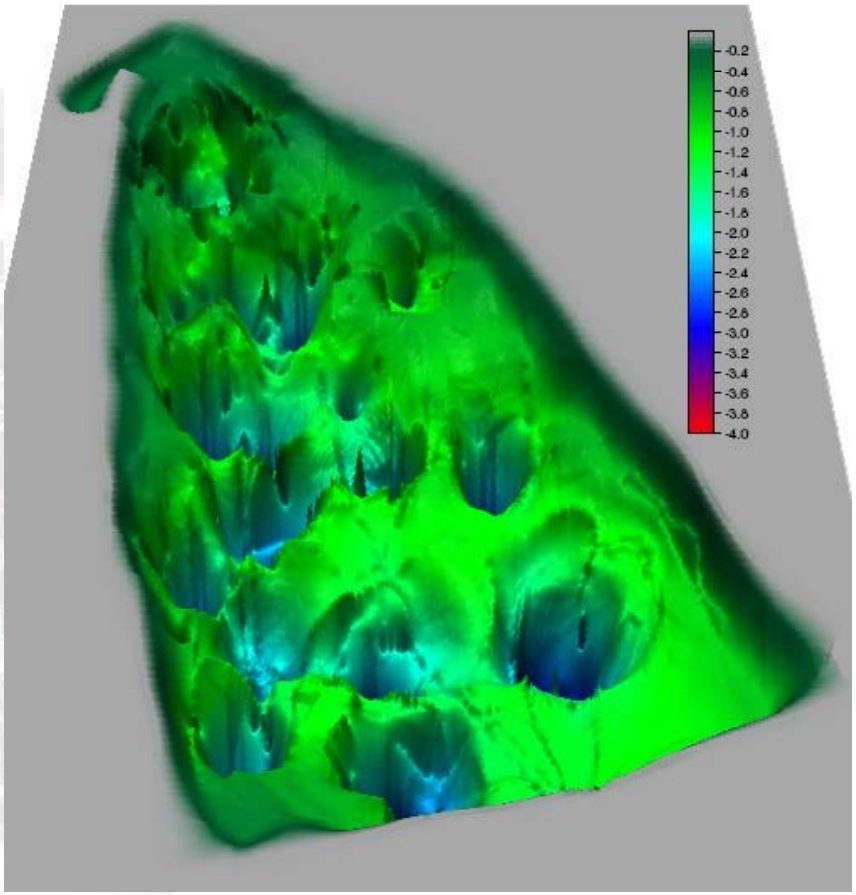
High Speed Mechanical Surface Aerator Effect

Topography of basin deposition created by vertical aerators



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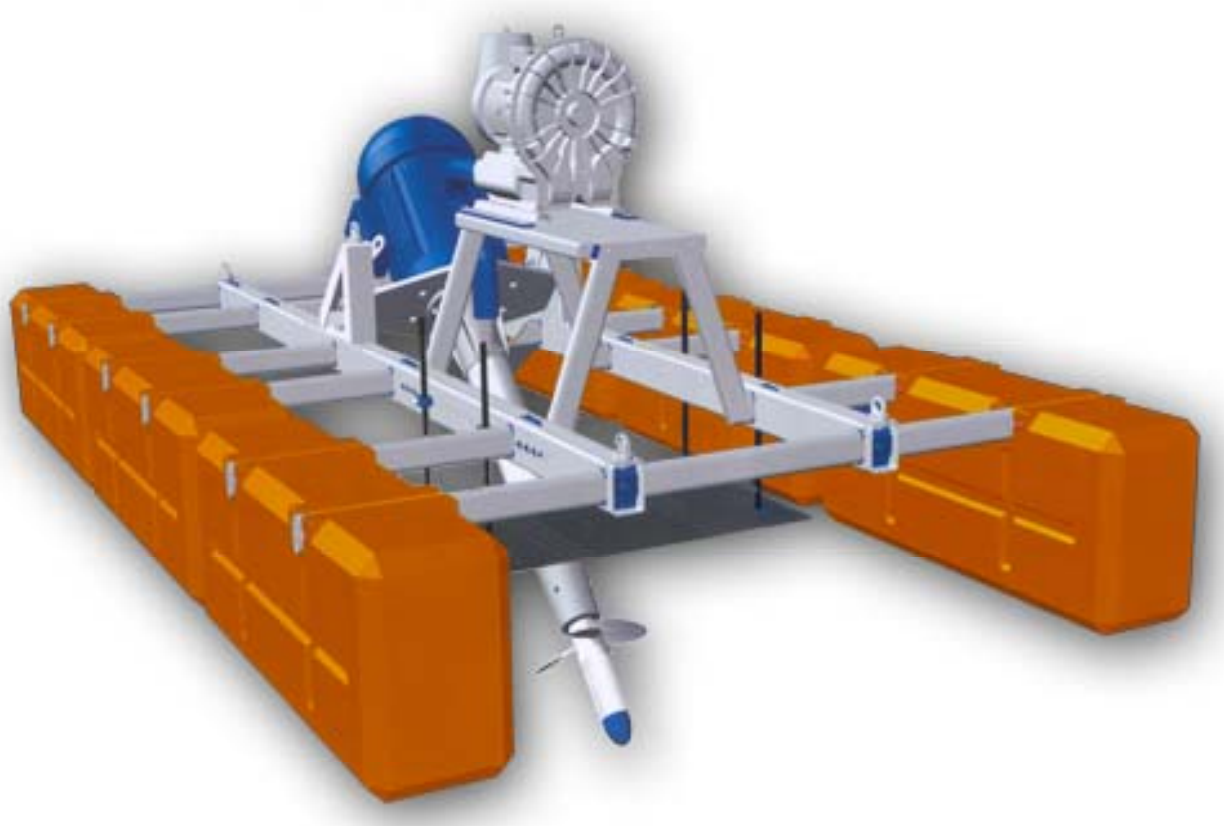
Horizontal Aspiration Aeration Technology

The Raptor™ is a technically advanced directional mixing and aeration system developed primarily for the industrial and municipal wastewater industry as a means of improving aeration, mixing efficiency, deposition control and minimizing foam development in all biological wastewater treatment processes using aerated basins, ponds, lagoons and tanks.



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Horizontal Aspiration Aeration Technology

HOW DOES IT WORK?

- The Raptor combines conventional aspirator aeration technology with blower assisted aeration. In common with the aspirator aerator, the Raptor consists of an electric motor fixed to a hollow shaft with a propeller mounted on the non-drive end. A patented double shear venturi diffuser is mounted below the propeller. By creating only fine bubbles <2.2mm, significantly improved oxygen transfer is achieved. This diffuser rotates with the propeller. Water passing over the diffuser therefore gains a tangential velocity component in addition to the already high axial velocity component generated by the propeller thrust. The hollow drive shaft is surrounded by a tubular housing containing a hydro-dynamic bearing. Atmospheric gases are introduced into the drive shaft at above atmospheric pressure generally by means of a side channel (regenerative) blower. The gases exit via the diffuser below the propeller.

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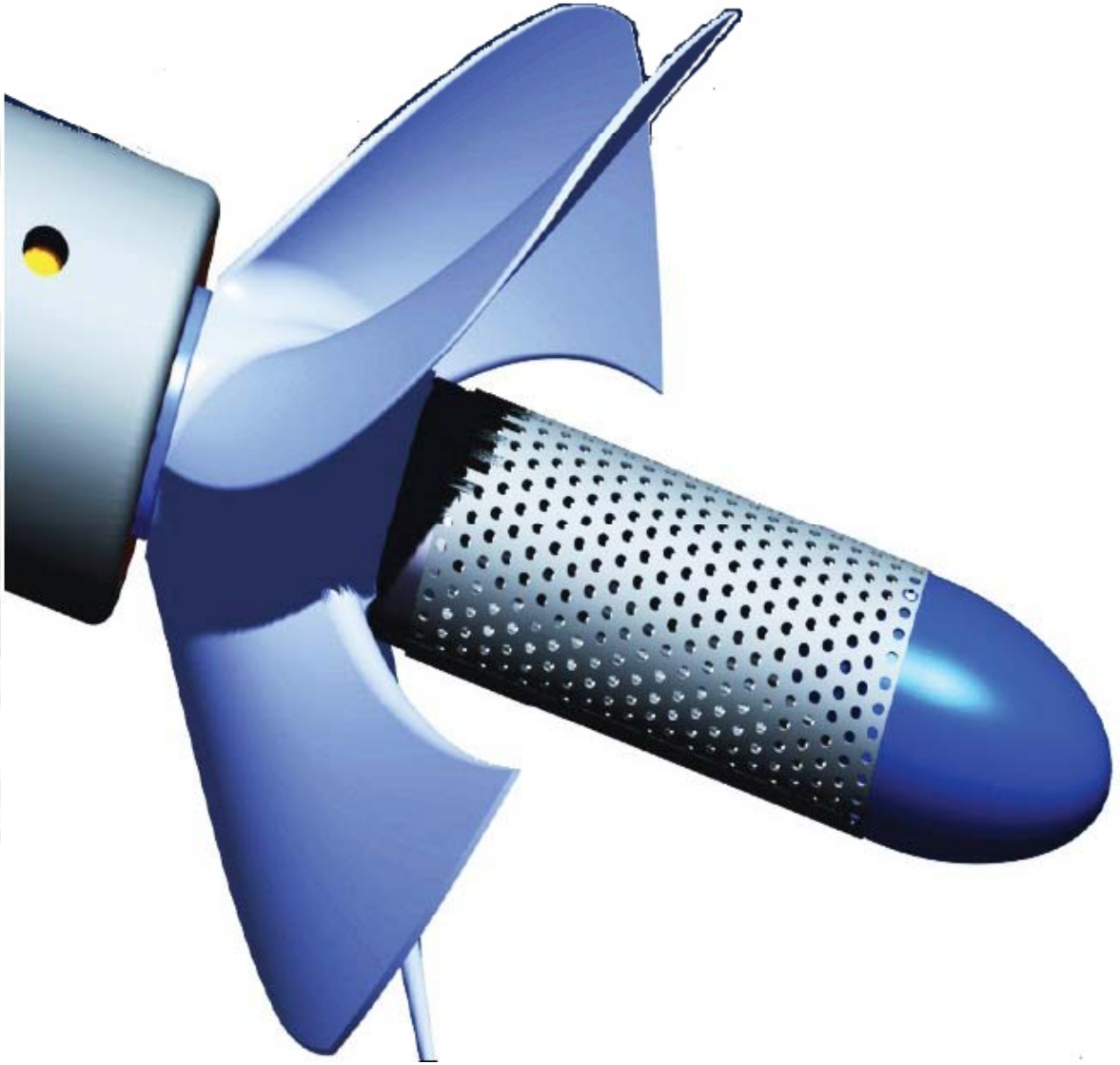
Horizontal Aspiration Aeration Technology



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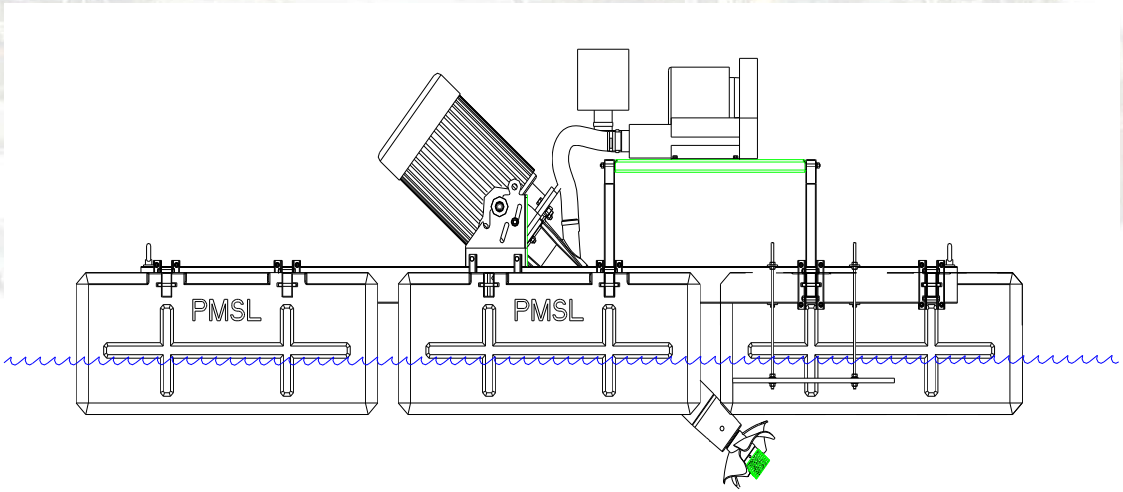
Horizontal Aspiration Aeration Technology

- This revolutionary and patented design achieves this first by controlling the volume and the pressure of introduced atmospheric gases, 21% being oxygen, and then controlling their characteristics as they come in contact with the liquor. The design determines the bubble size as well as the direction and velocity of the bubble plume. This in turn determines the dwell and contact time of the bubbles with the liquor.

- Compared with aerators discharging from the end of the drive shaft, the unique Raptor diffuser generates much smaller bubbles and subsequently much higher surface area per unit volume, which in turn enhances oxygen transfer potential. Therefore all gases are exposed to the double shear action as they exit the diffuser. Radial shear due to the rotation of the drive shaft and second, linear shear due to the water stream passing over the diffuser, created by the thrust from the propeller. It is the double shear action, which produces the small bubbles. The bubble plume is then dispersed by the rotating propeller in both vertical and horizontal vectors to maximize dwell time and in turn atmospheric gas interface with the water.



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Horizontal Aspiration Aeration Technology

The Raptor can operate in two modes to perform three operational functions. In nitrification mode the unit combines aeration and mixing and in de-nitrification mode the unit combines BNR (Biological Nutrients Removal)

The Raptor was developed because it was felt that alternative products were using outmoded base level technology, which was proving to be a high maintenance item. Clients commented that existing systems did not offer any degree of flexibility of operation such as variation of submergence or centre of gravity adjustment. Five key design points were targeted, which were determined to offer the most significant improvement on existing technology. These points are noted as follows:

1. **Plate Coupling**

   The universal joint has been replaced with a German made plate coupling manufactured from thin stainless steel plates. This type of coupling is far more suited to the application. The angular misalignment is less than 0.1° so the range of movement of a universal joint serves no purpose. Universals also require regular greasing and suffer from the effects of corrosion. The plate coupling has no moving parts, requires no servicing and is manufactured entirely from corrosion resistant materials.

2. **Hydroflute™ Bearing**

   The Raptor is installed with a new innovation in hydro-lubricated bearings known as Hydroflute™. The shallow axial water channels of a standard ‘cutless’ bearing have been replaced with a deeper spiral involute profile. The simple rotation of the shaft promotes a powerful pumping action, which increases the water velocity through the bearing. The main benefits are the remarkable cooling, greatly improved lubrication, self cleaning channels and also significantly reduced vibration due to the shaft being supported and guided over its entire circumference rather than rotating on a polygonal surface as is the case with axial channel bearings. The combined result of the above benefits is increased bearing life and reduced clogging and ragging.

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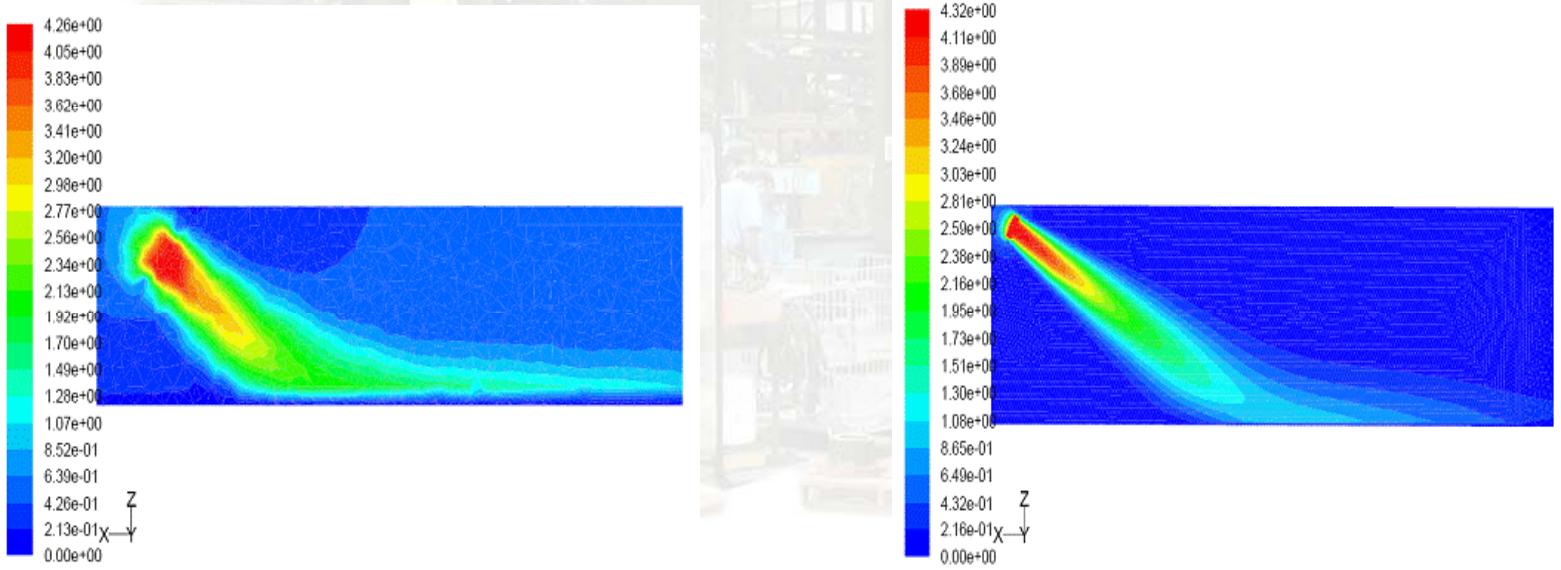
3. **Adjustable Submergence**

The Raptor is equipped with a mounting bracket, which allows for five different submergence positions at 50mm increments to enable simple insitu adjustment for tuning purposes. Combined with a range of available horse power, this feature allows for effective break up and control of particulate deposition to minimize the need for dredging and offer a more aggressive and easier adjustment alternative to baffles. With the use of our CFD Technology (Computational Fluid Dynamics), we can model these specifics for your basin.

Contours of Velocity Magnitude (m/s)



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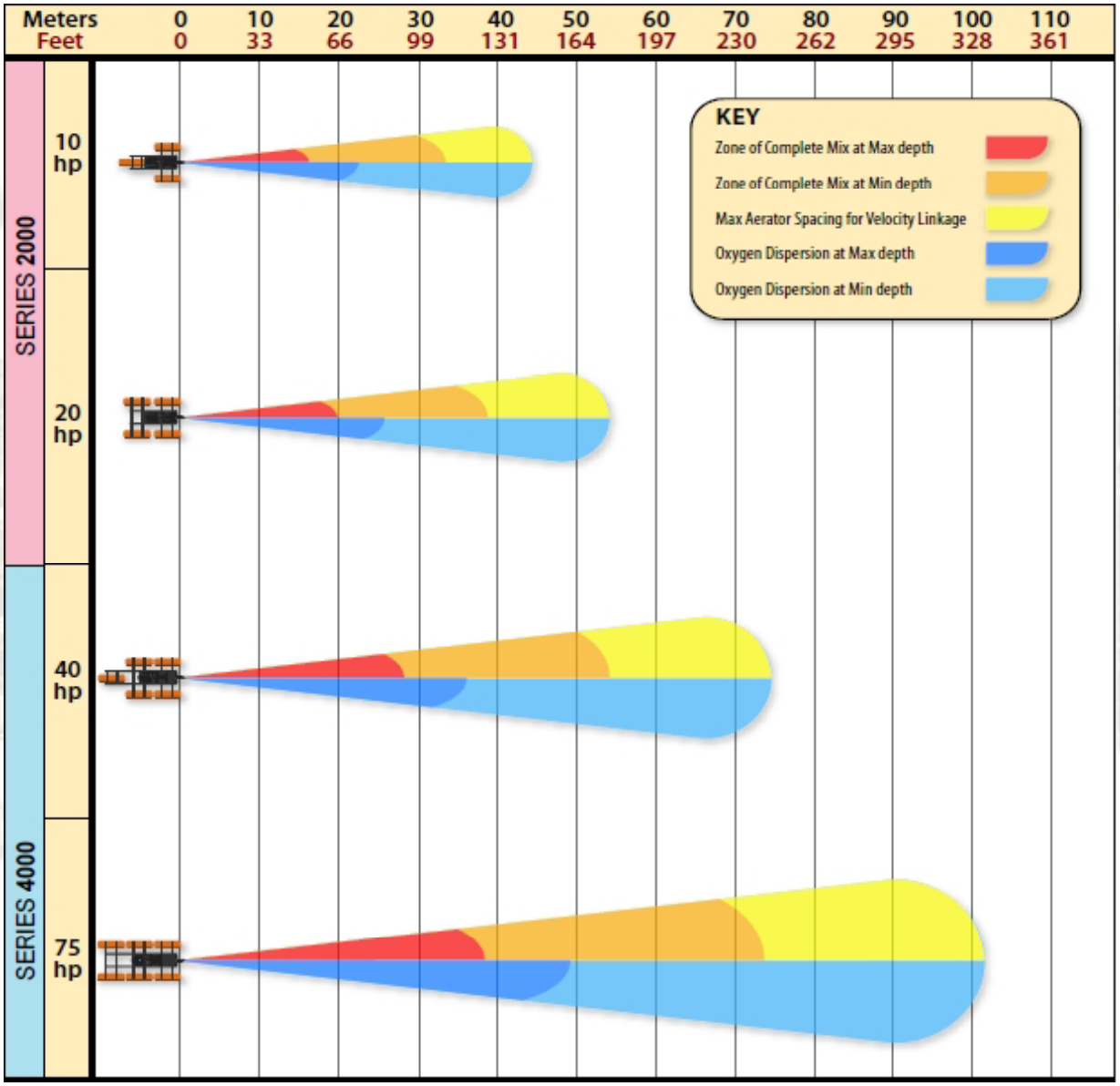
Horizontal Aspiration Aeration Technology



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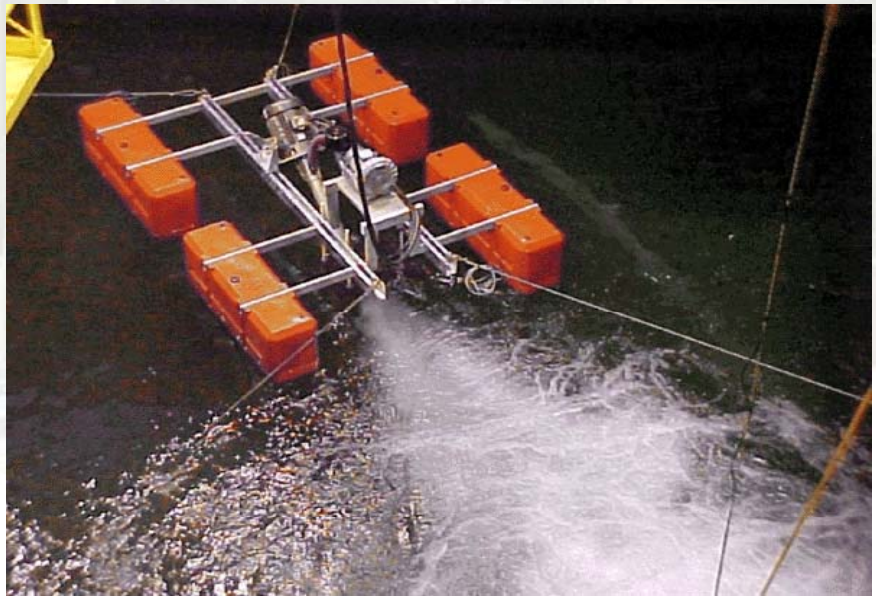
4. **Lineal Adjustment`**

   The aerator can also be adjusted forward and aft to enable perfect positioning to ensure a level attitude if for any reason the centre of gravity changes due to modifications to the aerator or to its mooring system or if equipment is added to the pontoon assembly.

5. **Pontoon System**

   The pontoon system like the aerator itself has been designed from scratch to meet the needs of end users by providing portability and long maintenance free service. It features easy assembly via a patented modular clip system. The floats are manufactured from high-density polyethylene using the rotational moulding process. Each float is filled with a closed cell polyurethane foam to eliminate any possibility of water ingress.



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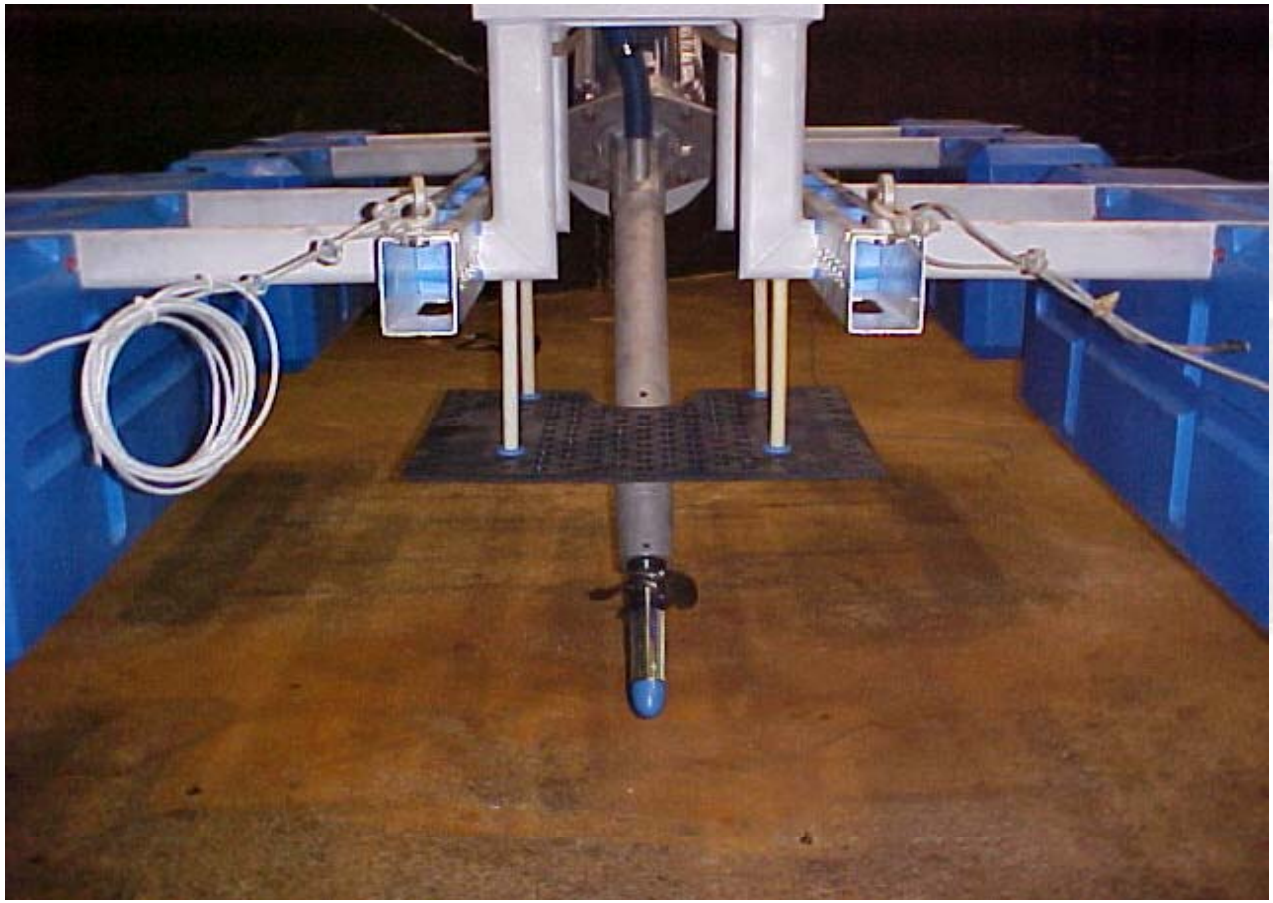
Horizontal Aspiration Aeration Technology

Also, our Vortex shield installation below the water surface ensures a vortex can never form and since the Raptor injects oxygen below the surface, foam development is substantially reduced.



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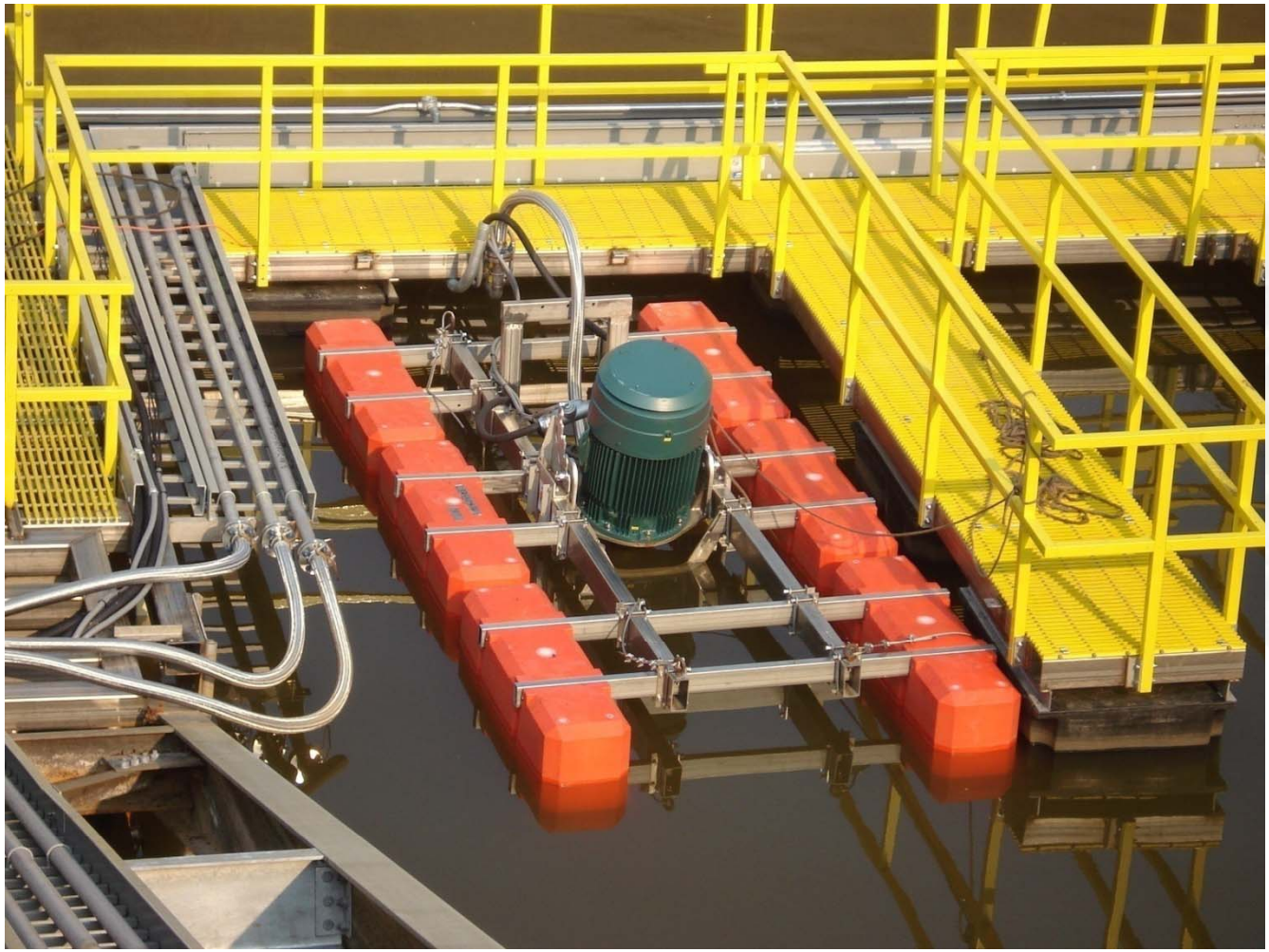
Application of High Purity Oxygen

For process conditions that would benefit or require substantially higher levels of O_2, the Raptor can be equipped to utilize HPO (high purity oxygen) to provide 10 – 14 lbs. O_2 / Hp Hr.



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Application of High Purity Oxygen

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Horizontal Aspiration Aeration Technology

Why Directional Flow

- Directional flow has to do with the amount of oxygen that is "consumed" by a lagoon system as opposed to the amount of oxygen that is delivered into a body of liquid (O_2 transfer). High speed donut type floaters and other types of surface units consume high levels of energy and splash vigorously, but have a minimal zone of influence in that they continue to add more oxygen to an already oxygenated zone. The oxygen simply returns to the surface and vents off the liquid. Because of this poor "mixing" capability, oxygen is continuously dropped on top of the bugs that are already satiated with oxygen. This contributes to the creation of "flower pots" or islands of dense oxygenation in an otherwise oxygen starved expanse.

- In essence, an aeration device is being asked to perform two different, competing functions. The first, it must deliver oxygen. The second, it must mix effectively so the oxygen is taken to the oxygen starved bugs and concurrently, the oxygen starved bugs must be brought to the oxygen delivery zone. The current high speed units do neither and can actually contribute to odor problems via their "aerosol effect". Competitive offerings that rely solely on diffuser technology are better than the high speed donuts, but can generate too coarse (large) of a bubble and more importantly, cannot create an entire lagoon rotation. The key to maximizing O_2 transfer is to use the kinetic energy generated by a properly circulating basin (it takes less energy to maintain circulation than it does to start it). By linking the flow from properly aligned Raptors, solids deposition is minimized, odor is reduced, short circuiting is eliminated and influent containing high levels of DO mixes with influent containing low levels of DO. Raptors are extremely efficient deliverers of oxygen (25% more than competitive offerings and 50% more than donuts) and has the potential to provide between 33% -60% electrical savings. With the Raptor, the input oxygen is higher, but more importantly the "consumed" oxygen (that which is not wasted because it is not proximal to the hungry bugs) is considerably more effective.

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Proof

For oxygen transfer in clean water we are using the American Society of Civil Engineers (ASCE) method with Na2SO3 + CoCl2 as a catalyst. We do testing in our 50' x 60' in ground vessel with the max depth of 32'. The vessel also has temperature control.

STATE-OF-THE-ART FACILITY AND TECHNOLOGY.

Designed for testing all mixing processes from beaker-size to scale-up tanks to true full-scale aeration testing in the 750,000 gallon indoor basin, the R&D lab is available to provide results of equipment upgrades, process improvements, and comparative studies. All results and test data are shared with customers and analyzed with the application engineer staff to ensure the data is understood and all options are explored.

Broadest experience evaluating the widest array of aeration technologies from mechanical (in virtually all its forms) to diffusion – making the unknown known.

All testing performed to ASCE guidelines for clean water aeration testing ensures objective comparison of alternate technologies taking the guess-work out of the design process – dispelling myths.

Standardized testing provides foundation for projecting "real world" performance to accurately predict effluent results – reducing the risks.

Most of the oxygen transfer tests for our customers are witnessed. The witness has access to all data collecting equipment during the test. If necessary we can call a third party to run the test and certify the data if a Certificate is required.

All of our tests are fully documented, traceable and we are ISO certified.

As the largest indoor environmentally controlled full scale testing facility in the world, we permit the engineering community, and our competitors to "certify" their performance characteristics. We only require a copy of the report. That data allows us to comfortably, and singularly, understand true performance of all market products. Most importantly, however, we continually design products with superior performances.

It is important to note that all testing is done in clean water. Results are obtained in identical conditions and therefore are ideal for comparison.

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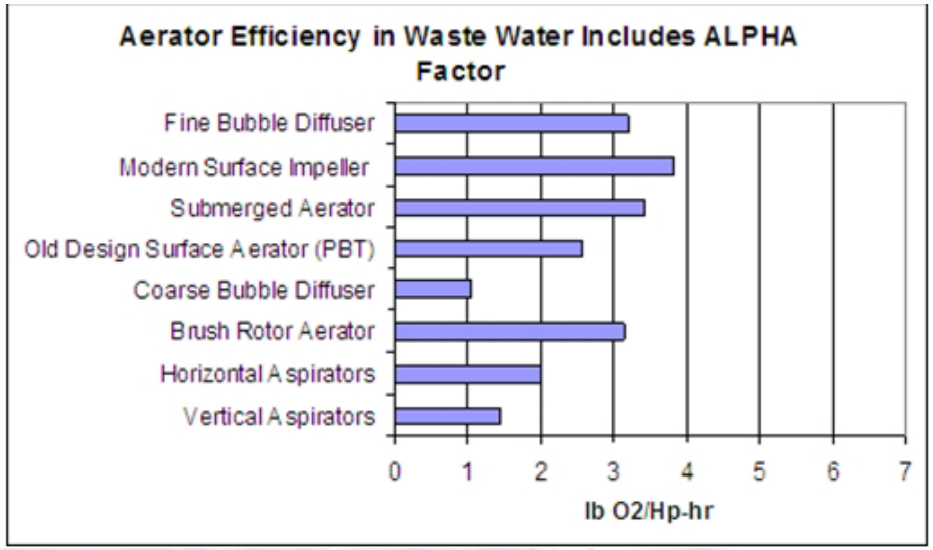
Proof

	ALPHA RANGE
Vertical Aspirators	0.85-1.2
Horizontal Aspirators	0.85-1.2
Brush Rotor Aerator	0.85
Coarse Bubble Diffuser	0.4-0.7
Old Design Surface Aerator (PBT)	0.85
Submerged Aerator	0.85
Modern Surface Impeller	0.85
Fine Bubble Diffuser	0.3-0.6

Based on industry literature and our experience, the value of ALPHA factor varies with equipment type and composition of waste.



In the presence of surfactants the surface tension drops, less energy is required for dispersion; therefore bubble sizes are smaller so the interfacial necessary for oxygen transfer grows. On the other hand, surfactants can prevent coalescence and block oxygen transfer by forming a layer on the interface.

This is clearly seen in waste water oxygen transfer. However, vertical and horizontal aspirators do not follow this rule. Both are high speed, so at the interface, they produce very high turbulence. The surface is reformulated by high shear and forced coalescence takes place. This explains why the ALPHA factor can have value above 1.0 for high speed aerators.

In a lagoon, in addition to the aeration process produced by a mixer, oxygen is also absorbed through the surface. Surface waves improve transfer by creating a larger surface area and also easing transfer from the surface layer deeper into the body of water. The waves are caused wind and/or by operating equipment. Horizontal aspirators like the Raptor affect a much larger body of water than vertical aspirators by providing strong internal circulation within a lagoon, therefore providing an improved oxygen transfer mechanism from the saturated surface into oxygen poor regions.

Within any lagoon there will be pockets of stagnant zones due to the shape and size of the lagoon. These areas will become anaerobic close to the bottom and aerobic close to the surface.

We believe the above described natural processes are responsible for up to 45% BOD reduction depending upon a lagoon's configuration. This reduction would not be possible without installation of horizontal aspirators that create waves and convection in large areas of a lagoon.

Our testing/experience shows that the effect of natural forces combined with the Raptor's high speed horizontal aspiration and extended dwell time created by driving smaller bubbles deep into the body of water, allows for the effective oxygen transfer rate to reach 3 lb O2/ Hp-h

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Methods for Testing Confirmation of Performance

Dissolved Oxygen

- DO meters - As measured for both close proximity to aeration units and non-direct aerated areas i.e. basin linkage (must be uniformly positioned and requires that liquor must move past the sensor at one foot per minute for accurate readings).

Total Suspended Solids

- Monitor for increase in TSS.
- Visual confirmation of deposition removal.

Odor

- Will initially increase if deposition is re-suspended and processed and will decrease upon equalization.
- If deposition is not engaged, odor will decrease due to elimination of “aerosol” effect.

Energy Savings

- Oxygen transfer per HP hour is improved (up to 50%). Option is to take improved O_2 at equal HP or equal O_2 at reduced HP (33% - 60%)

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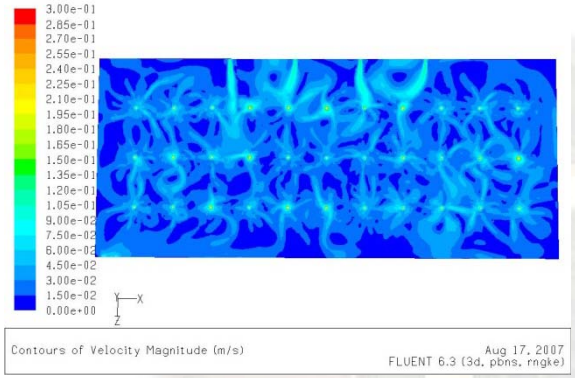
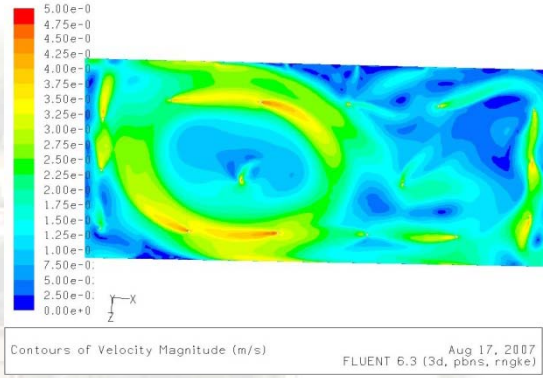
Horizontal Aspiration Aeration Technology

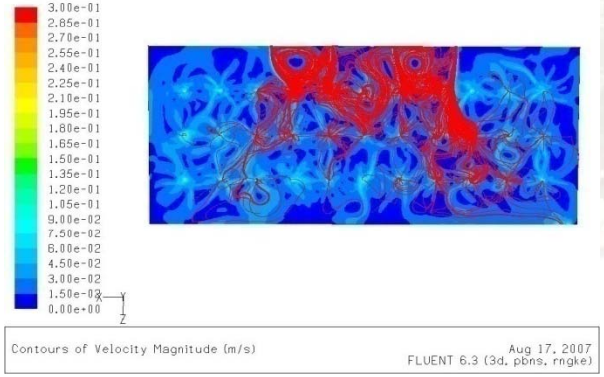
CFD Lagoon Simulation showing velocity profiles of Vertical Aerators



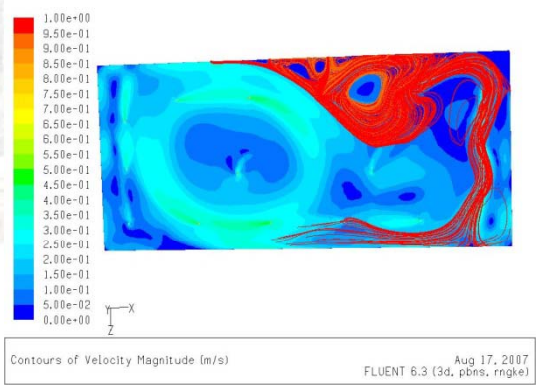
CFD Lagoon Simulation showing velocity profiles of Raptor™ directional flow



The light Blue represents approximately 0.2 ft/s> Aerators are clearly seen as light spots. Long ribbons on the top represent Inlet flow. Mixing is very zonal with heavy deposition at the Bottom due to low velocity.



Directional aerators induce circular flow in the lagoon. The flow is very high and most of the lagoon is in motion



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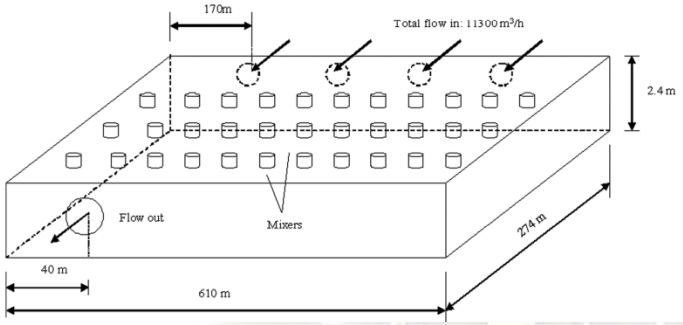
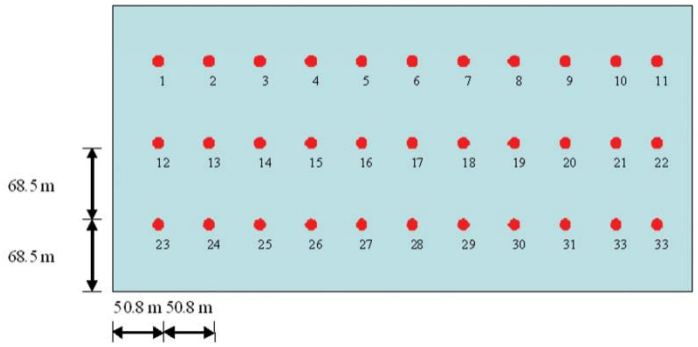
Horizontal Aspiration Aeration Technology

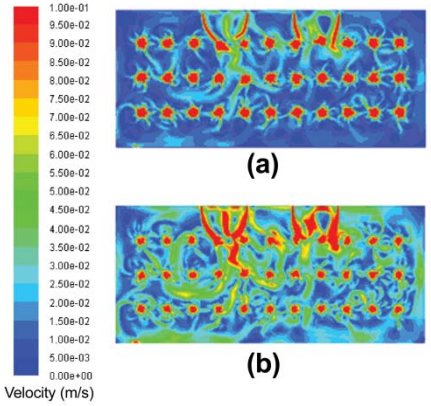
Large lagoon with 33 mixers represented by 33 momentum sources (1,453,444CFD cells, existing design)



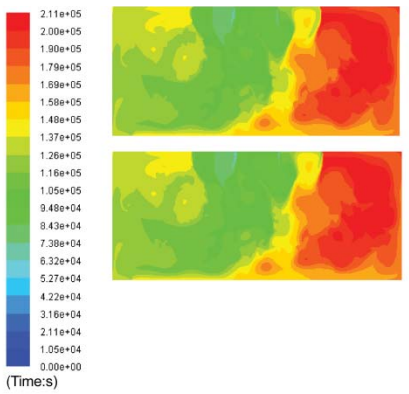
Lagoon configuration and dimensions



Lagoon configuration and dimensions for placement of mixers



Display of velocity contours at x-y planes at z-0.1m (a) and z=1.4m (b)



Display of Local Average Residence Time contours at x-y planes at z=0.1m and z=1.4m

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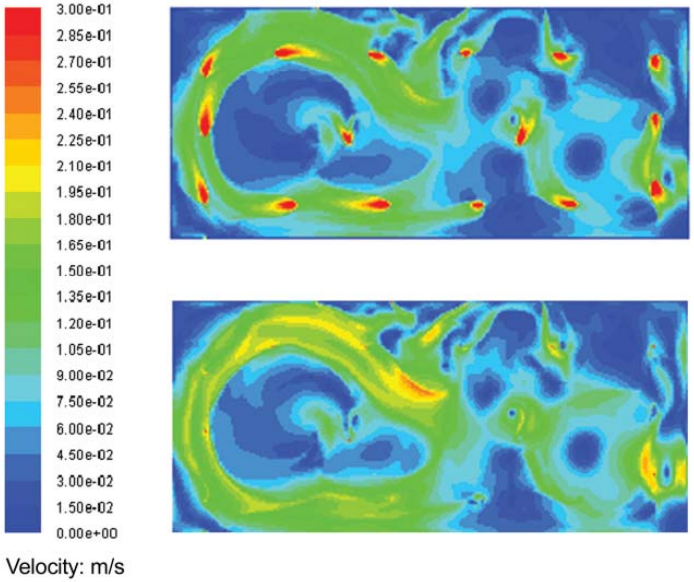
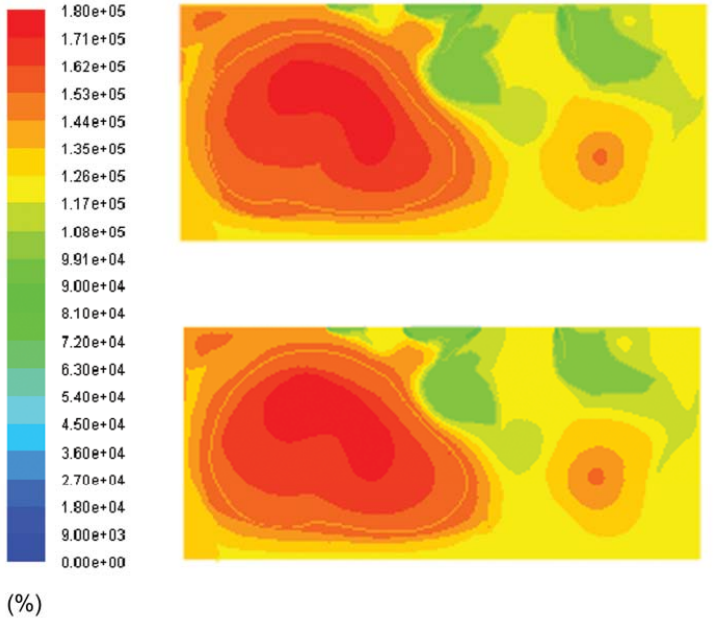
Horizontal Aspiration Aeration Technology



Display of velocity contours at x-y planes at elevation z-0.1m and z-1.4m



Display of Local Average Residence time contours at x-y planes at z=0.1m

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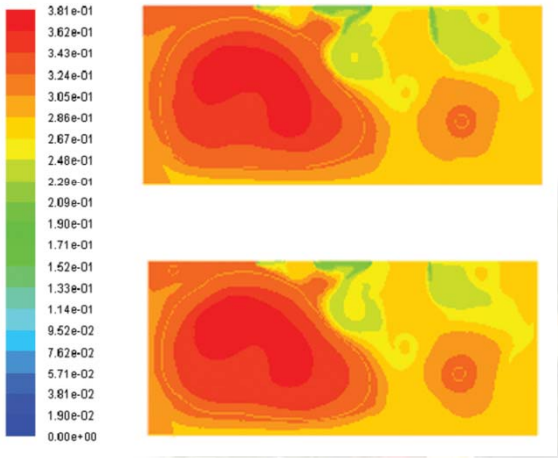

Display of BOD removal contours at x-7 planes at z=0.1m
(Average BOD removal in the lagoon = 30.4%)

Conclusion

The results of this simulation show that directional aerators induce very strong circulation in the lagoon thus preventing solids settling and short circuiting of flow in/out.

The model predicts comparable BOD removal with vertical and horizontal mixers. However, the vertical mixers use twice the power of horizontal mixers i.e. 16 horizontal mixes produce better residence time distribution than 33 vertical mixers 15 kW each.

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Case Studies

Case in point: Southern paperboard mill has serious BOD and deposition issues.

Short term objective: To provide directional O_2 into the untreated area and to drive deposition to the outlet. **Long Term:** Decrease energy costs and, in addition to providing required O_2 and deposition removal/control, improve Residence Time Distribution.

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Case Studies

Extrapolation of customer's deposition areas created from current vertical aerators

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Case Studies

Short Term Solution: Initial placement and flow direction of 4 Raptors to provide directional O_2 into the untreated area and to drive deposition to the outlet (X marks placements). The outlet has good gravity flow to pull the deposition through to the next lagoon for easy dredging.

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Case Studies

Long term solution: Utilize thirty six 75 Hp Raptors to create internal controlled loops within the lagoon. In addition to providing required O_2 and deposition control, this configuration will improve Residence Time Distribution by putting entire body of water into controlled rotational motion. We will position the Raptors accordingly to generate 12 internal loops within the lagoon using 3 Raptors for each loop as shown below. Leaving theses Raptors as permanent, begin to move back in the lagoon in stages, replacing the vertical aerators with Raptors to attack the next area of deposition and use the developing improved gravity flow to link the newly suspended material (and increased O_2) to the preceding Raptors. Ultimately all vertical aerators would be replaced with Raptors creating a permanent, self conditioning and sustaining lagoon process.

Estimated R.O.I. in excess of 60% from reduced Hp usage and reduction/elimination of chemical and process treatments.

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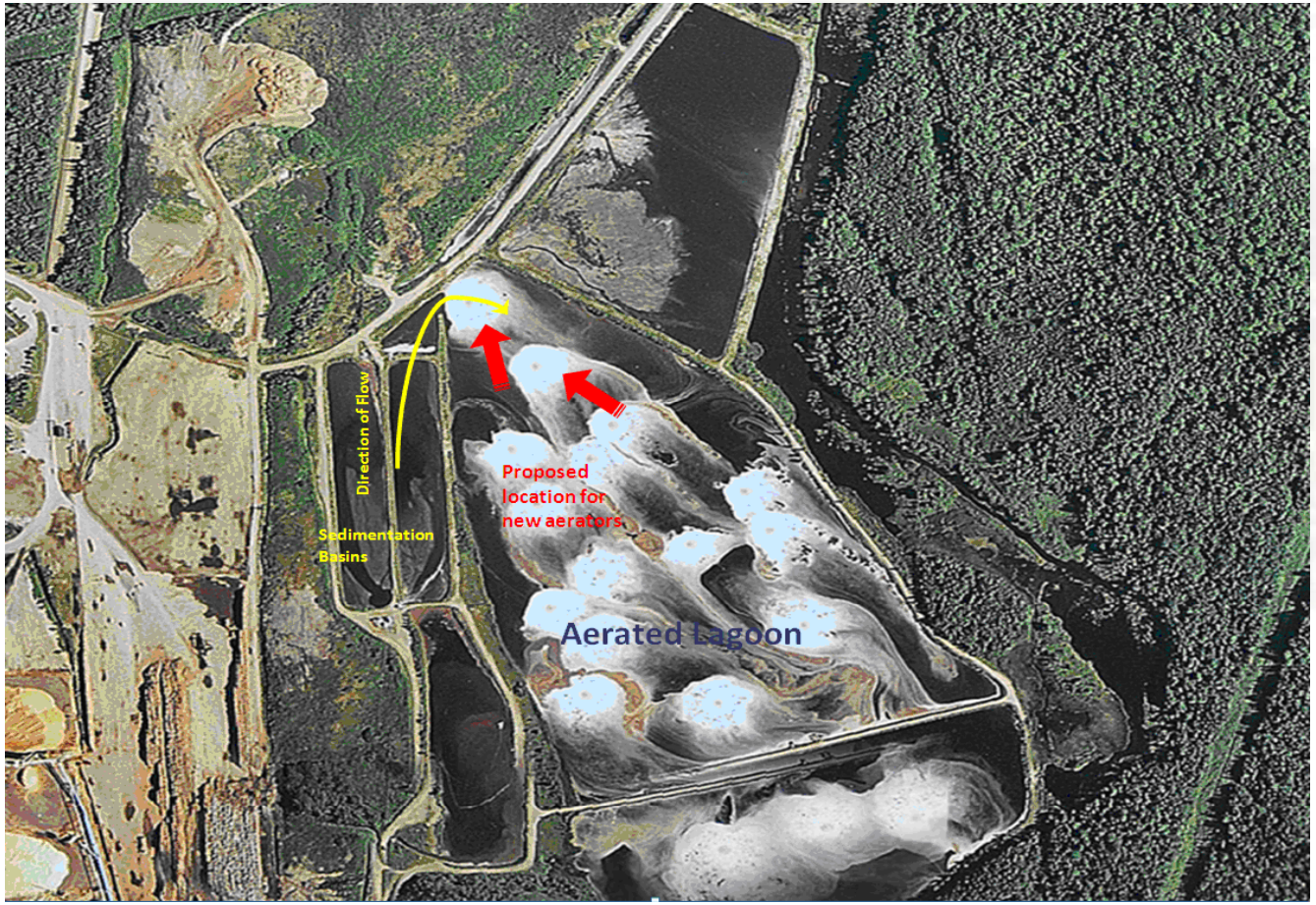
Case Studies

Canadian customer had a “letter of warning” for non-compliance. Using satellite imagery of their lagoon and with an understanding their flow patterns, we were able to recommend optimal placements of Raptors at their inlet point to provide an immediate oxygen transfer boost.



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Case Studies

- 30 days after installation of the Raptors, the environmental “letter of warning” was lifted.

- 9 months after installation, the customer hired an outside consultant to “measure” their lagoon using mini robotic boats equipped with sophisticated sonar instrumentation. The resulting topography showed that in the area of the Raptors, the deposition had been removed.

Raptors can effectively be used in conjunction with existing equipment to “optimize” process and then eventually replace older technology units as they fail

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Case Studies

- Vertical aerators had high energy cost for low oxygen production
  - Major issues with deposition build up
  - Verticals had high maintenance costs

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Case Studies

- Replaced 12 verticals with 8 Raptors, maintained O2 and cut 300 HP/Day
  - As remaining verticals fail, they're replaced with Raptors
- Achieved 100% recovery of depth in targeted areas of deposition

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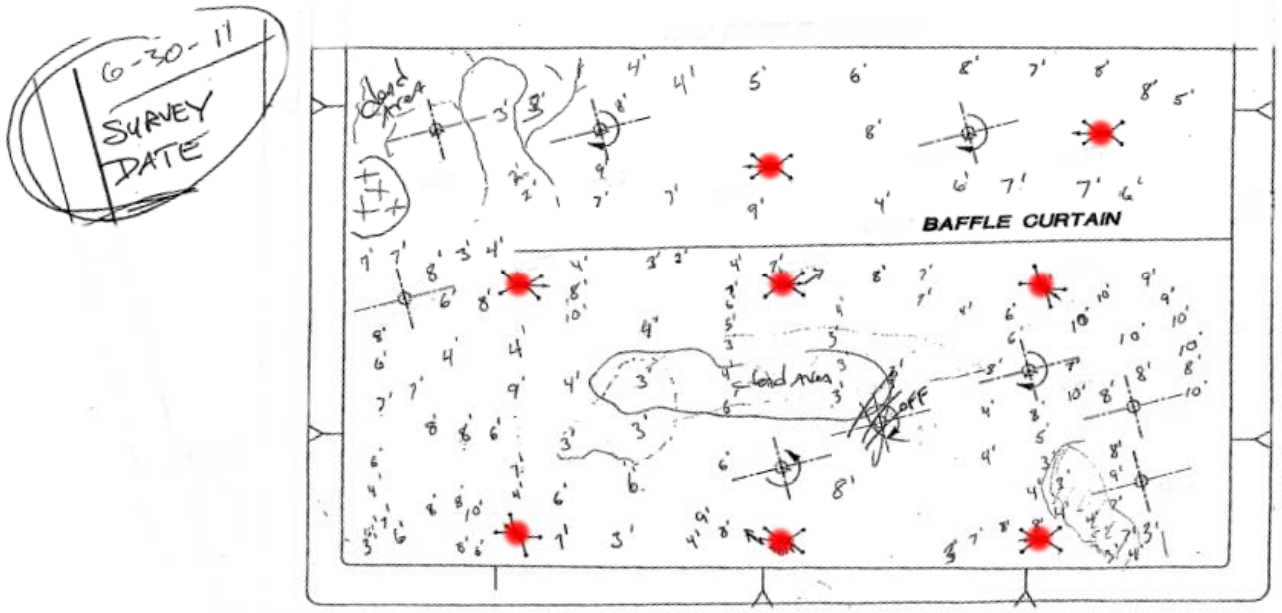
No Doubt of Functionality

•Midwest mill had severe deposition from years of running combination of LSSA's & Verticals. In many cases only 2'-3' (original design depth 14').

•Mill has been running eight 75 Hp Raptors since March and recently completed topography survey. Where Raptors are linked, the numbers speak for themselves.



● = Raptor Location

Measured Depths

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Case Studies

Vertical aerators created excessive foam resulting in legal action from floating foam on nearby highway.

Mill wanted to pursue recently enacted government rebate incentives for energy savings.

Sludge build up from verticals resulted in 60% reduction in processing capacity and use of expensive curtains.

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Case Studies

- Linked Raptors accentuated O2 from verticals and knocked down foam
- Eliminated curtain
- Qualified for government energy rebates

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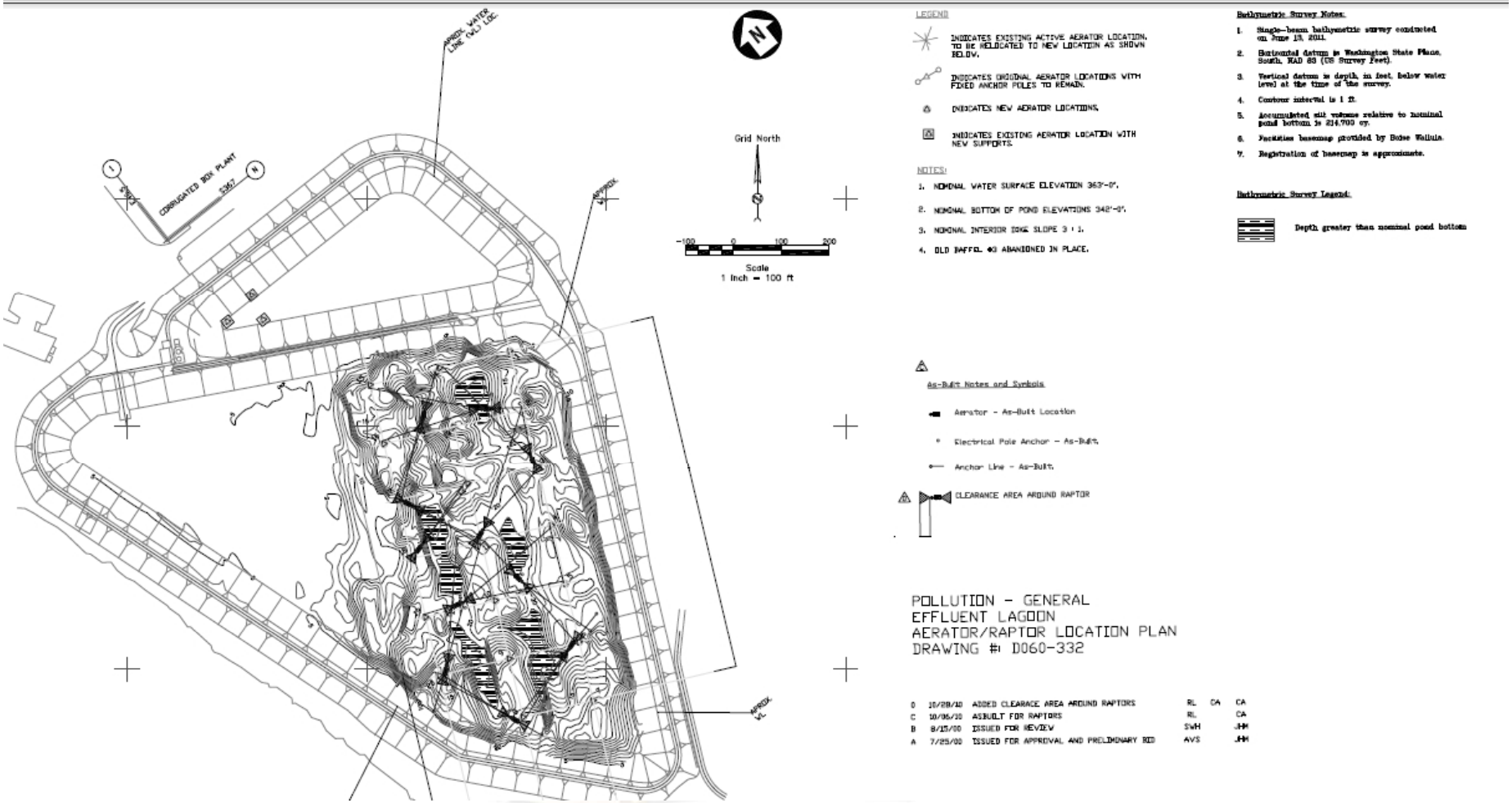
No Doubt of Functionality



Survey report from Associated Underwater Services (UAS). Determined there was 214,700 cubic yards of sludge. The JPS sludge survey Pre-Raptor was 228,830 cubic yards = 14,130 cubic yards of sludge removed in 6 months.

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Case Studies

- Vertical aerators had high energy cost for low oxygen production
- Generated high foam levels requiring expensive anti-foam chemical suppression system that was not operable during winter months.
- Aerosol effect contributed to odor complaints.

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Case Studies

Mill replaced all verticals with Raptors

- D.O. is up 40% versus their old verticals. Odor from aerosol effect is eliminated.
- Foam and most of the deposition they targeted has been cleaned out down to the bedrock.
- They’re doing all of this running 45% less Hp than they used to with their old verticals
- Energy savings qualified for government rebates paying 50% of all equipment and installation costs

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PnP Mill Indonesia

Value Proposition Example

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Calculations:

The Mill's vertical aerators facilitate 2 lbs of O2 per Hp/hour.

Raptors facilitate 3 lbs of O2 per Hp/hour.

33 Vertical Aerators X's (75 Hp) = a total of 2,475 Hp X's 2 lbs/O2/HpHr = 4,950 lbs/O2/HpHr X's 24 Hours = 118,800 lbs/O2/day

22 Raptors X's (75 Hp) = a total of 1,650 Hp X's 3 lbs/O2/HpHr = 4,950 lbs/O2/HpHr X's 24 Hours 118,800 lbs/O2/day

Raptors will provide equal lbs/O2 per day of targeted oxygen using 825 Hp less per day, plus targeted deposition removal/control, odor reduction, foam control, improved mixing efficiency and improved cooling uniformity.

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PNP India

Value Proposition Example

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PNP India

Value Proposition Example

Calculations:

Retro-fit of 54 current LSSA Impellers with 54 Talon™ Impellers

Current 100 HP LSSA's facilitate up to 3.2 lbs of O2 per Hp/hour =

54 LSSA's x 100 HP = 5,400 Hp x 3.2 lbs/O2/HpHr = 17,280 lbs/O2/HpHr x 24 hours = 414,720 lbs/O2/day

Talons facilitate up to 4 lbs O2 per Hp / hour

54 Talons x 100 HP = 5,400 Hp x 4.0 lbs/O2/HpHr = 21,600 lbs/O2/HpHr x 24 hours = 518,400 lbs/O2/day

Retro-fit with Talons will provide equal O2 using 1,350 less HP per day or provide 103,680 more lbs O2 per day using equal HP.

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THANK YOU

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