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February 11, 2021

Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, D.C. 20426

Re: Gregory B. Jarvis Power Project, FERC No. 3211
Response to Request for Additional Information

Dear Secretary Bose:

The Power Authority of the State of New York (Power Authority) is in the process of relicensing the Gregory B. Jarvis Power Project (Project), FERC Project No. 3211, using the Integrated Licensing Process (ILP). The Power Authority submitted its Final Application for a New License (Application) with the Federal Energy Regulatory Commission (FERC or the Commission) on July 31, 2020.

On November 13, 2020, FERC issued an Additional Information Request identifying one deficiency in the Power Authority's license application (Schedule A) regarding Exhibit G Project boundary GIS data, and five additional information requests (Schedule B) pertaining to aquatic, terrestrial, and cultural resources. By letter dated December 18, 2020, the Power Authority provided the requested Project boundary GIS data and additional information pertaining to cultural resources.

Enclosed please find responses to the remaining additional information requests issued by the Commission, including:

- Hinckley Reservoir trout stocking information (Attachment A)
- Supplemental mussel survey information (Attachment A)
- Supplemental Common Loon census information (Attachment A)
- Dissolved Oxygen Enhancement Feasibility Study Report (Attachment B)

We look forward to continuing our work together as the Commission and other resource agencies complete their environmental review related to the Commission's issuance of a new license for the Project. If there are any questions regarding this information, please direct them to the undersigned at (315) 323-4443 or cindy.brady@nypa.gov.

Sincerely,

Cindy Brady

Cindy Brady
Manager, Licensing

ATTACHMENT A – RESPONSE TO ADDITIONAL INFORMATION REQUESTS

Aquatic Resources

FERC AIR 3: Table 4.5.1.2-3 indicates that no trout stocking occurred in Hinckley Reservoir in recent years (2018 and 2019). So that staff can determine if stocked trout are expected to be present in the reservoir, and therefore potentially susceptible to impingement and entrainment at the project, please consult with the New York State Department of Environmental Conservation (NYSDEC) and indicate whether trout stocking will continue in Hinckley Reservoir or is being discontinued.

Power Authority Response:

The Power Authority requested available trout stocking data from NYSDEC via email dated November 18, 2020. In response to this request, NYSDEC noted that all trout stocked between 2018 and 2020 were Rainbow Trout. NYSDEC plans to continue stocking the reservoir annually. In 2018 NYSDEC stocked 4,350 trout, in 2019 they stocked 5,000 trout, and in 2020 they stocked 14,340 trout. Rainbow Trout were evaluated in the Power Authority's *Assessment of Fish Entrainment and Turbine Passage Survival* Study Report, filed with the Commission on October 30, 2019, which concluded that the overall rate of fish entrainment at the Project is low.

FERC AIR 4: So that staff can better assess the potential effects of project operation on the apparent mussel population (of eastern floater) that resides in the project reservoir, please provide the following additional details that were not included in the mussel report filed on October 30, 2020:

- [FERC AIR 4a] Although the report includes a map of the sampling areas, it is unclear whether these sampling areas included the areas of concern for potential stranding that were originally reported by a landowner, and subsequently assessed in-person by NYSDEC during its September 9, 2020 site visit. Therefore, please clarify if your sampling areas included the areas of concern identified by the landowner and assessed by NYSDEC.
- [FERC AIR 4b] The report indicates that "…in addition to the exposed shoreline, areas underwater to a depth of approximately 2 feet were searched." Please confirm these "underwater" observations were made from the shoreline (i.e., by looking into the water from the shoreline) rather than by other means (e.g., snorkeling, view scopes, or SCUBA).
- [FERC AIR 4c] The report states that various 'size classes' of eastern floater were observed and provides an example picture of mussels of various sizes, but provides no shell length data. Therefore, please include, to the extent available, any mussel length data (dead, alive, or spent) that were recorded during NYPA's surveys.

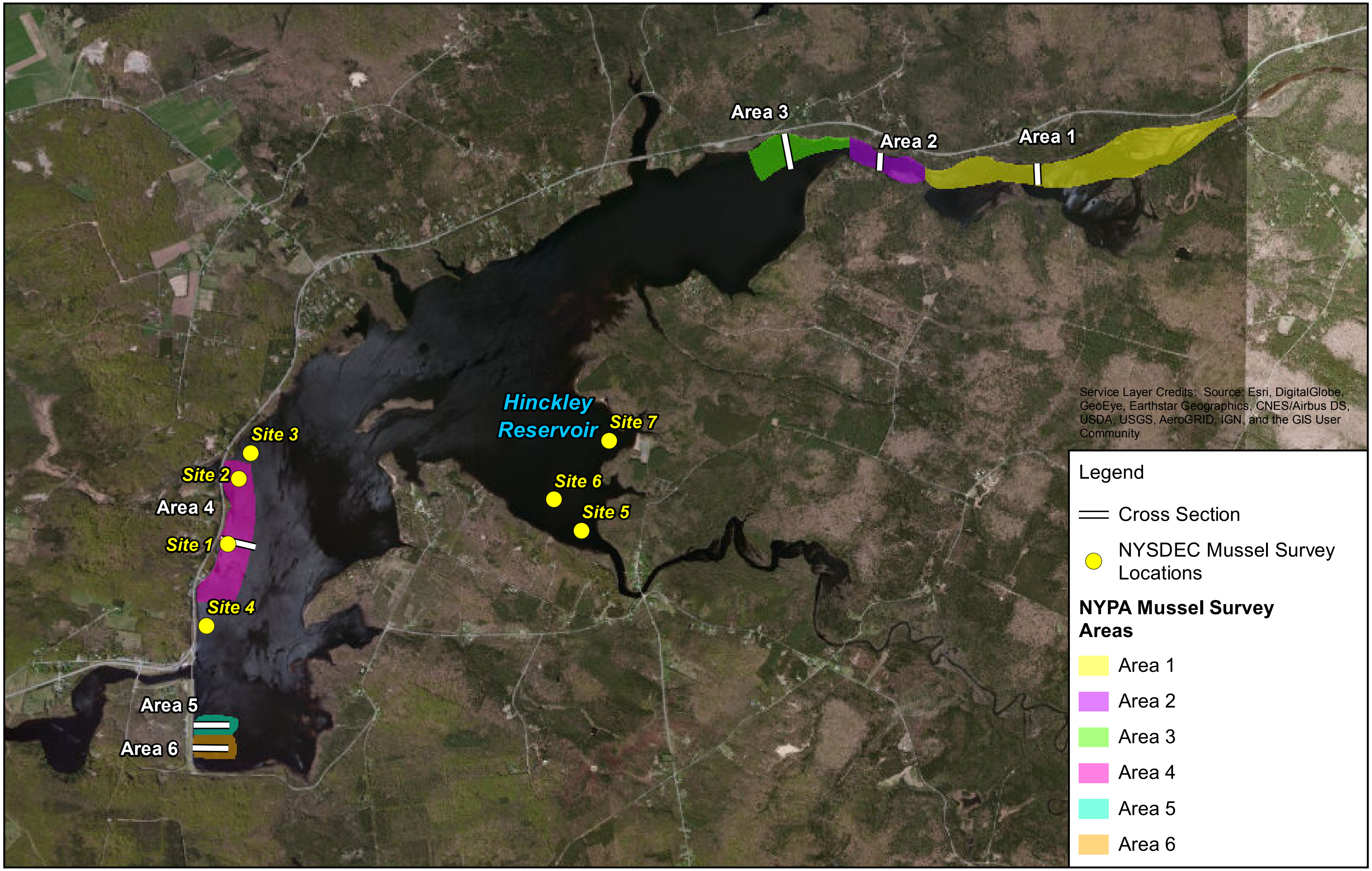
Power Authority Response:

In response to FERC AIR 4a, the Power Authority consulted with NYSDEC via email dated November 18, 2020. In their response, they noted that the area informally surveyed by NYSDEC included the areas identified by the public as having spent, dead, and live mussels. These sites were identified as Sites 5, 6, and 7 in the NYSDEC report titled *Summary of Informal Freshwater*

Mussel Survey in Hinckley Reservoir, dated September 9, 2020 and shown on Figure 1 below. NYSDEC Sites 5, 6, and 7 are different from the sites surveyed by the Power Authority. The sites surveyed by the Power Authority are different from those surveyed by NYSDEC because the Power Authority conducted their initial survey prior to receiving locational information from NYSDEC. Figure 1 presents a map depicting Power Authority survey locations as compared to NYSDEC survey locations.

Regarding FERC AIR 4b, underwater observations noted in the Power Authority's report were made from the shoreline and while wading and did not include snorkeling, view scopes, or SCUBA.

Finally, in response to FERC AIR 4c, formal mussel length measurements were not recorded during the survey; however, informal measurements of two mussels were made using a field notebook (see Photo 1). As observed in Photo 1, the larger mussel is approximately 9 cm long, while the smaller mussel is approximately 6 cm long. In addition, several photos of mussels placed against a pencil were also taken for context (see Photos 2-5). The mussel observed in Photo 2 is approximately 5.5 cm long. The same mussel is observed in Photo 3 (i.e., the smaller mussel). The larger mussel observed in Photo 3 is approximately 6.5 cm long.



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Gregory B. Jarvis Project
(FERC No. P-3211)

Figure 1
Comparison of Power Authority
and NYSDEC Mussel Survey Locations

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Photo 1. Informal mussel measurements using field notebook

Photo 2. Mussel placed along field notebook lines for reference

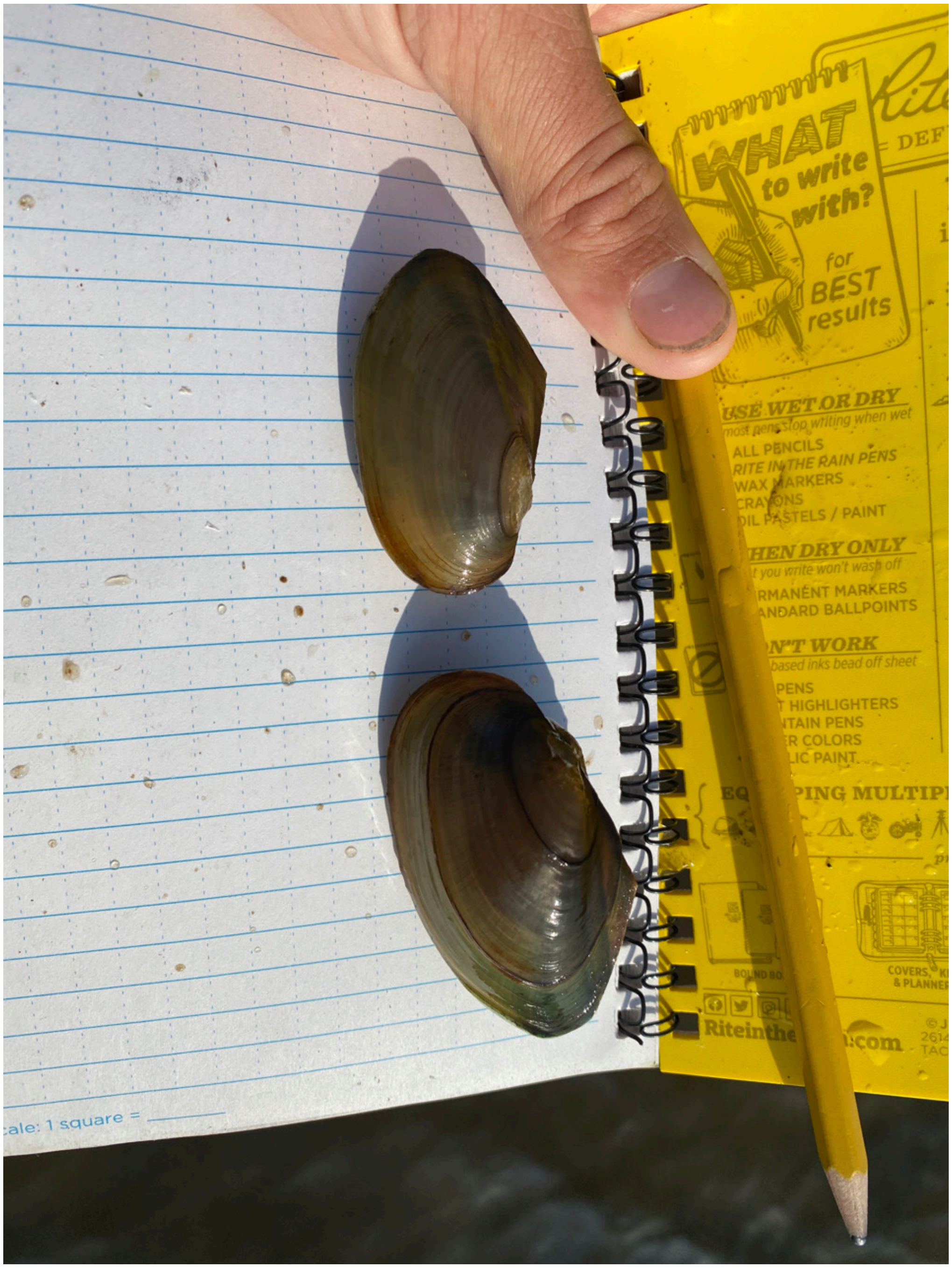


Photo 3. Mussels placed along field notebook lines and next to pencil for reference

Photo 4. Mussel placed against pencil for reference

Photo 5. Mussel placed against pencil for reference

Terrestrial Resources

FERC AIR 5: Table 4.8.1.2-3 provides a summary of common loon census data through the 2019 field season. In its July 10, 2020 comment letter, Citizens for Hinckley Lake notes that a consistent number of loons have been present on the project reservoir since early spring 2020. Please provide any information on the number of loons observed within the project boundary during the 2020 season, including any evidence of breeding activity.

Power Authority Response:

Based on preliminary results from the 2020 Loon Census conducted by the Adirondack Center for Loon Conservation (https://adirondackatlas.org/adkloon/), two (2) adult loons were observed at Hinckley Reservoir in 2020. The Licensee is not aware of any evidence of breeding activity.

ATTACHMENT B – DISSOLVED OXYGEN ENHANCEMENT FEASIBILITY STUDY REPORT

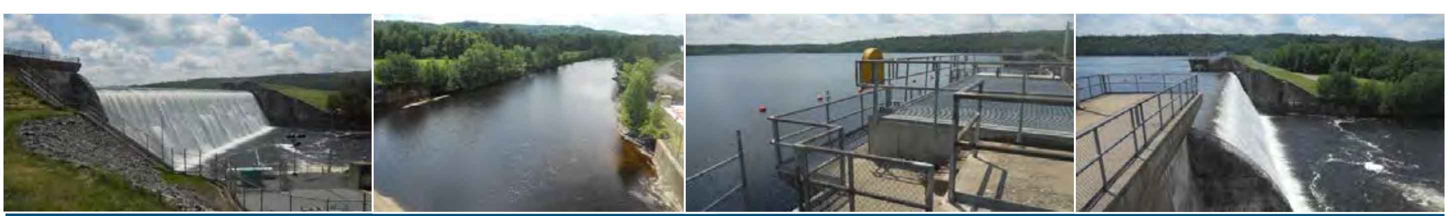
DISSOLVED OXYGEN ENHANCEMENT FEASIBILITY FINAL REPORT

Prepared by: Gomez and Sullivan Engineers

February 2021

GREGORY B. JARVIS PROJECT RELICENSING

FERC NO. 3211



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List of Abbreviations

^{o}	degree
BCD	Barge Canal Datum
C	Celsius
cfs	cubic feet per second
El.	Elevation
EPRI	Electric Power Research Institute
FERC	Federal Energy Regulatory Commission
fps	feet per second
ft	feet
ft^2	square feet
ILP	Integrated Licensing Process
NY	New York
NYPA	New York Power Authority
NYSDEC	New York State Department of Environmental Conservation
PAD	Preliminary Application Document
PSP	Preliminary Study Plan
RSP	Revised Study Plan
SPD	Study Plan Determination
SUNY	State University of New York
the Commission	Federal Energy Regulatory Commission
the Power Authority	Power Authority of the State of New York
the Project	Gregory B. Jarvis Power Project (FERC No. 3211)

Executive Summary

Introduction

The Power Authority of the State of New York (d/b/a "New York Power Authority" and referred to as "the Power Authority") is licensed by the Federal Energy Regulatory Commission ("FERC" or "the Commission") to operate the Gregory B. Jarvis Power Project ("Jarvis Project" or "Project") (FERC No. 3211-NY). The original FERC license expires on July 31, 2022. As part of the relicensing studies for the project, water quality data were collected in 2018 and 2019. The data indicated that the dissolved oxygen (DO) concentrations in the tailrace were below New York State standards[1] at times in the summer when the Project was generating. The lower DO concentrations are attributed to hypoxic conditions in the deeper portions of the Hinckley Reservoir, which stratifies during the summer months, and lack of reaeration through the turbines. Based on these findings, FERC requested that a Dissolved Oxygen Enhancement Study be conducted to assess dissolved oxygen enhancement options at the Project.

This report presents the results of the Dissolved Oxygen Enhancement Study performed in accordance with the Study Plan filed with the Commission on January 15, 2020. The objective of the study is to assess the feasibility, potential effectiveness, and costs of various DO enhancement measures, including operational and physical options.

Screening

The first step in the study was conducting a desktop literature search to review different dissolved oxygen enhancement methods. The range of potential alternatives reviewed included reservoir, forebay, powerhouse, and tailrace aeration measures. The alternatives were summarized in a table and reviewed using existing engineering drawings of the Project. Screening criteria included, but were not limited to, effectiveness, disadvantages, project suitability, and testing capacity. The alternatives were prioritized based on assessments made by Power Authority Operations and Engineering staff. Surface aeration in the tailrace, gas (air or oxygen) injection into the penstock, and the utilization of Gate No. 4 were selected for additional evaluation.

Feasibility

The information gathered during the literature search was used to determine the feasibility of the three selected DO enhancement technologies for the Project taking into account site-specific details. Existing Project engineering drawings, correspondence with equipment manufacturers, and product literature were used to inform the feasibility analyses and to develop preliminary opinions of probable construction costs (OPCCs).

[1] The area immediately downstream of the Reservoir, from Hinckley Dam to Prospect Dam, is classified by the New York State Department of Environmental Conservation as Class B (T). For trout waters (T), the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L.

Surface aeration technologies which could be installed in the Project tailrace were investigated, including surface aerators, aerating fountains, and aspirating aerators. Depending on the predicted oxygen transfer rates and Project flow range, between 2 and 15 100 horsepower (HP) aspirating aerator units would be required to provide adequate oxygen in the tailrace[2]. Based on the literature review, a 100 HP unit requires 3,600 SF of surrounding area to operate at peak efficiency. With this requirement approximately 54,000 SF of area is needed for the installation of fifteen 100 HP units to address low DO concentrations at the maximum Project discharge of 1,800 cfs. The aeration potential for this alternative is difficult to predict at the Jarvis site because these technologies are typically not installed in riverine environments where air/oxygen bubbles have shorter residence times, as compared to lakes or ponds. This technology was found to be infeasible because the space requirements exceed the area available in the tailrace (9,100 SF).

The second alternative investigated was the installation of a penstock air (or oxygen) injection system. The Project penstock has two 12" steel vents at the 15' diameter intake in the old sluice gate chambers 2 and 3 which are used when the penstock is dewatered or filled. No other vents or taps into the penstock exist. Injection into the penstock would ensure more air or oxygen was passed into the water downstream into the tailrace. The required system would need to replace between 0.5 – 2.4% of the water flow through the powerhouse (1.5 – 43.2[3] cubic feet per second (cfs)) in the penstock with air depending on the dissolved oxygen concentrations at the intake. The system would include seven variable drive air compressors installed downstream of the right non-overflow section of the dam in the vicinity of the powerhouse connected to hoses installed through the penstock vents which may be difficult to install. The effects of additional air injected directly into the penstock upstream of the turbines needs to be evaluated further because additional air in the penstock may increase the frequency for cavitation repairs or turbine maintenance shutdowns. Injecting oxygen would require less volume than an air system, however, it would require maintaining a consistent oxygen supply on-site and create safety hazards.

The third alternative, using Gate No. 4 to improve tailrace DO concentrations, was tested in August 2019. Although the Gate No. 4 intake is located at a similar elevation to the powerhouse intake, the outlet freely discharges into the tailrace, reaerating the discharge. Testing on August 7, 2019 showed that Gate No. 4 releases had concentrations of approximately 8.0 mg/L over a range of flows tested and that tailrace DO concentrations could be improved with the mixing of low DO water from the turbine intake with higher DO water discharged from Gate No. 4. The existing gate is manually operated using an electro-mechanical operator with personnel onsite. The electro-mechanical operator currently can't be operated remotely. The gate could continue

[2] Aerating fountains and surface aerators have much lower transfer capabilities compared to aspirating aerators.
[3]The range for required volume of air injection is based on an oxygen deficit of 0.5 mg/L at during a powerhouse discharge of 300 cfs (0.005 x 300 cfs = 1.5 cfs) and an oxygen deficit of 2.4 mg/L at 1800 cfs (0.024 x 1800 cfs = 43.2 cfs).

to be manually operated or be modified to automate the gate enabling remote operation

.Aside from capital construction costs for replacing the gate, there are generation impacts and limitations due to the reservoir releases stipulated by the 2012 Operating Diagram. Using Gate No. 4 to improve tailrace water quality would reduce the generation at the Project in the summer/low DO months of June through September to between 13.3 and 25.7% of current production[4].

Capital Cost

Existing Project engineering drawings and product literature were used to inform preliminary opinions of probable construction costs (OPCCs). Unit costs for aspirating aerators and OPCCs for the two other alternatives are presented in Table E-1. The OPCC includes mobilization, contingencies, as well as engineering and construction administration. The construction costs for the penstock injection OPCC include air compressor equipment and hose costs, and costs to provide power to the compressors. The construction costs for automation and replacement of Gate No. 4 include the replacement of the gate, providing power to the gate, welding or pipe connection work required for the replacement, connection of the existing supervisory control and data acquisition (SCADA) system, and installation of a surveillance and warning system for Gate No. 4 releases. Each of the alternatives described above as well as operating Gate No.4 manually would require dissolved oxygen monitoring equipment to be installed in the tailrace and the intake. Costs for purchasing dissolved oxygen monitoring equipment vary between $20,000 and $70,000 depending on whether streamside or buoy technology was installed or whether the data was collected manually through the data loggers or data was sent remotely to a central location. Over the duration of a 40-year FERC license, permanent real-time dissolved oxygen equipment would need to be purchased twice assuming a life span of 20 years.

[4] Generation reduction analysis was based on the minimum observed intake dissolved oxygen concentration of 3.6 mg/L.

Table E-1. Tailrace DO Mitigation Capital Costs

Alternative	900 cfs Powerhouse Discharge Capital Cost ($2021)	1,800 cfs Powerhouse Discharge Capital Cost ($2021)
Surface Aeration (Per Unit Purchase Costs[5])	$248,000	$465,000
Penstock Air Injection OPCC	$443,000	$766,000
Gate No. 4 Automation OPCC	$439,000	$439,000
Real-Time-DO Monitoring	$20,000 - $70,000	

[5] Purchase price only. Does not include mobilization/demobilization or installation.

1 Introduction

The Power Authority of the State of New York (d/b/a “New York Power Authority” and referred to as “the Power Authority”) is licensed by the Federal Energy Regulatory Commission (“FERC” or “the Commission”) to operate the Gregory B. Jarvis Power Project (“Jarvis Project” or “Project”) (FERC No. 3211-NY). The original FERC license expires on July 31, 2022. As a part of the licensing process, the Power Authority conducted a Tailwater Water Quality Study between May and October 2018 and prepared an Initial Study Report (ISR) which was filed with FERC on May 8, 2019. This assessment indicated that the dissolved oxygen (DO) concentrations in the tailrace were below New York State standards[6] at times in the summer when the project was generating. The lower DO concentrations are attributed to hypoxic conditions in the deeper portions of the Hinckley Reservoir, which stratifies during the summer months.

On or before July 10, 2019, the Power Authority received comments on the study from the New York Department of Environmental Conservation (NYSDEC) and FERC. NYSDEC requested an additional 12 months of tailwater water quality monitoring. FERC requested that a new Dissolved Oxygen Enhancement Study be conducted to assess dissolved oxygen enhancement options at the Project. In accordance with the FERC study request, the Power Authority developed a Dissolved Oxygen Enhancement Study Plan and provided a draft to the NYSDEC and U.S. Fish and Wildlife Service (USFWS) for review on December 20, 2019. Both agencies concurred with the Study Plan as proposed. The Dissolved Oxygen Enhancement Study Plan was filed with the Commission on January 15, 2020.

In addition, the Power Authority conducted voluntary water quality monitoring from July 2019 through October 2, 2019 to further inform water quality dynamics in the Project tailwater and potential DO enhancement measures to be evaluated in the *Dissolved Oxygen Enhancement Study*. The results of voluntary monitoring during the summer of 2019 were provided as an attachment to the Dissolved Oxygen Enhancement Study Plan.

The resulting water quality data collected in 2019 demonstrated that stratification of the Hinckley Reservoir occurs during the summer months. Since the hydropower intakes withdraw water from the bottom of the reservoir below the thermocline, instances of low DO concentrations (below state standards) can occur in the Project tailrace . Releases from the powerhouse are not currently re-aerated as they enter the tailrace. The lowest tailrace DO measurement recorded in 2018 and 2019 was 3.65 mg/L. Field testing of Gate No. 4 for potential reaeration during generation was tested in August 2019.

[6] The area immediately downstream of the Reservoir, from Hinckley Dam to Prospect Dam, is classified by the New York State Department of Environmental Conservation as Class B (T). For trout waters (T) these standards provide that, the minimum daily average shall not be less than 6.0 mg/L, and at no time shall the concentration be less than 5.0 mg/L.

The objective of the study is to assess the feasibility, potential effectiveness, and costs of various DO enhancement measures, including operational and physical options.

2 Literature Review

The purpose of this task was to conduct a literature search of existing research and case studies to collect data on water quality enhancement technologies and methods. Table 2.1-1 provides a general overview of water quality enhancement at hydroelectric projects, including anticipated costs, potential benefits, general disadvantages, the suitability of the technology to the Project, and the potential for testing the technology. The technologies were ranked from the most applicable to the least applicable at the Project. A series of figures illustrating the various technologies/methods are presented in Appendix A.

The review of water quality enhancement technologies/methods included reservoir, forebay/intake, powerhouse/turbine, tailwater, and Project operational adjustments. Technologies that included water quality improvements between the withdrawal zone upstream of the intake and the tailrace were prioritized over those which focused on improving watershed or overall reservoir water quality because they are more within the control of the Power Authority.

The technologies are sorted into three categories:

- Green/triangle for improvements/technologies which are known to achieve the target dissolved oxygen concentration;
- yellow/circle for technologies which could potentially be suitable to the Project;
- red/square for technologies or improvements which are not suitable to the Project.

Table 2.1-1. Dissolved Oxygen Enhancement Technologies/Methods used at Hydroelectric Projects

Ranking	Technology	General Description	Anticipated Costs	Potential Benefits	General Disadvantages	Project Suitability	Testing Capacity
▲	Project operation modifications (Using Gate No. 4)	• Bypassing flows downstream past turbines. • Passing flows through Gate No. 4	• 5,655 MWh in generation losses between June and September[7] • Potentially retrofitting Gate No. 4 with Howell-Bunger valve or fixed cone valve.	• Field testing and monitoring in August 2019 indicated that passing flow through Gate No. 4 enabled the Project to maintain average daily DO concentrations of at least 6 mg/L in the Project tailrace.	• Lost generation can make this technology economically undesirable. • Spill flows can increase wear on bypass structures and adding bypass structures can be cost-prohibitive.	• Flows can be passed through Gate No. 4 although this reduces the generation revenue at the project. • Based on monthly inflow data during low DO periods (June – August) the project spills less than 5-10% of the time).	• Yes – this method was tested in August 2019.
●	Surface tailrace aerators	• Aerators are mounted at an angle on floats and anchored to the tailrace. • The aerators induce oxygen transfer between the air and water surface using a rotor which creates a strong mixing current of air and water downward.	• Design, engineering, installation, and operation of the system • Periodic maintenance includes the replacement of bearings. • Surface aerators should be spaced between 10 – 30 feet apart to maximize oxygen transfer.	• Performance of aerators is fairly predictable in non-moving bodies of water.	• Initial equipment costs can be high. • Sites with tailwater depths less than 10 feet, flows lower than 2000 cfs, or oxygen deficits greater than 3 mg/L could require very large surface areas to be efficient. • The system may suspend sediment and increase turbidity. • Surface aerators may have noise impacts depending on the size and number of units. • Aerators spaced close together have reduced oxygen transfer rates.	• The performance and oxygen transfer resulting from the installation of these aerators in moving water is less predictable. • Space in the Project tailrace is limited to approximately 9100 SF.	• Not likely – surface aerators would need to be purchased or rented
●	Penstock gas injection	• Air injected directly into the penstock through existing ports or a port ring. • Air is passed downstream through the turbine into the tailrace.	• Design, engineering, installation, and operation of the aeration system • Air compressors or oxygen supply tanks and potential modifications to the penstock.	• Can be effective at sites with limited alternative venting options (i.e. Kaplan turbines).	• Limited potential for using forced air due to nitrogen supersaturation. • Explosion/combustion hazards associated with oxygen storage. • Gas injection upstream of the turbine can reduce the unit's efficiency. • Potential cavitation damage to turbines if high volumes of gases are required.	• Required pressure to inject air at Jarvis would be approximately 30 PSI • The lack of distance between the injection point near the butterfly valves and the turbines could potentially lead to cavitation problems.	• Testing would require an air compressor or oxygen source. • Should be studied further prior to testing due to potential impacts on turbine.
●	Forebay/Intake aeration (air/oxygen injection)	• Fine bubble diffuser systems located within the withdrawal zone (as close as 200 feet from the intake), • Systems supplied with air or pure oxygen which takes advantage of high pressures/ currents in the forebay to increase oxygen transfer to aerate water passing through the turbine.	• Design, engineering, installation, and operation of the aeration system • Purchasing and maintaining air compressors or oxygen supply on-site • Replacement of the diffusers every 10 years	• Oxygen transfer efficiency can approach 100% with sufficient depth. • Well-suited for high-head, hydraulic capacity (>1,000 cfs) with large DO deficits (>4 mg/L). • Effective at sites with limited alternative venting options (i.e. Kaplan turbines).	• Improper location can lead to problems with incomplete oxygen transfer • Can lead to corrosion of the turbine equipment. • Oxygen, not air, must be used in deep reservoirs due to possible nitrogen supersaturation.	• A diffuser system close to the powerhouse has the potential to introduce additional non-absorbed oxygen directly into the intake and could lower turbine efficiency and increase corrosion of hydro mechanical equipment. • It is anticipated that adjustable anchors for the diffusers would be required due to uneven surface of the reservoir bed.	• No – these systems are engineered and sunk into place and require on-shore mechanical and electrical utilities and either air compressors or oxygen tanks.

[7] Analysis for generation reduction estimate is provided in Section 3.3 of the report.

Ranking	Technology	General Description	Anticipated Costs	Potential Benefits	General Disadvantages	Project Suitability	Testing Capacity
●	Labyrinth weir	• Low-head structures built in a zig zag pattern across a tailrace, typically 2 – 5 feet high, where air is entrained as flows pass over the weir and hit the plunge pool surface below.	• Design, engineering, and installation of weir • Maintenance, clearing debris from the weir • Some loss of revenue due to lost head • Design of a removable weir section or gates to lower the tailwater when tailrace DO levels are low.	• If available free head, can produce large increases in DO (5+ mg/L), requires no power to operate.	• Capital costs can be high and the performance of the weir can be difficult to predict. • Weirs are non-navigable and can block fish movement. • Weirs also reduce the net head at hydroelectric projects by increasing the tailwater elevation.	• Revenue could decrease due to lost head. • NYPA staff stated that maintenance would be a concern. • Increasing the tailwater at the powerhouse by 2 – 5 feet could overtop the lower platform at the downstream end of the powerhouse. • Optimum aeration occurs between flows of 0.43 – 0.70 cfs/LF with maximum flow rates of 5.37cfs/LF. For the maximum flow rate/LF of weir the required weir length would be approximately 335 LF based on the max. powerhouse flow of 1800 cfs. • Weir sizing equations recommend an approximate weir height of 2.5 feet.	• No. Even if modeled, impacts on DO could be difficult to predict.
●	Draft tube venting	• Injection ports in draft tubes immediately downstream of turbine are used to introduce air into the flow.	• Design, engineering, and installation of the aeration system	• This method uses existing (or modified) structures.	• Oxygen uptake potential is limited due to the size of the pipes conveying air into the draft tube (2-6 inches in diameter on average). • Installation of equipment can be difficult and expensive. • Performance can be difficult to predict. • Generation output can be reduced by 1-5%.	• The maximum deficit during water quality monitoring occurred on August 7, 2018. The tailrace DO deficit was 2.4 mg/L. Draft tube venting is not recommended for sites with DO deficits greater than 2 mg/L. This improvement would likely need to be implemented in conjunction with another technology.	• Not likely – vents are not present currently.
●	Reservoir epilimnion pumps for intake aeration or local destratification	• A floating platform in the reservoir attached to the shore or dam with a submerged impeller capable of moving large volumes of oxygen –rich, epilimnetic water into the lower DO withdrawal zone.	• Design, engineering, installation, and operation of the aeration system • Costs to install a system to power the pump • Most commercial mixers have a 10-year life span.	• Field demonstrations at hydropower sites have demonstrated this technology can be simple and effective. • Tests have shown favorable results.	• May eliminate cold water releases supporting downstream fisheries. • Can disturb reservoir sediments. • The effectiveness of this technology is limited in reservoirs with depths less than 150 feet or during low surface DO periods. • Performance of pump is limited in a strongly stratified reservoir. • The anchor system must be able to withstand wind/wave action, full range of headwater changes, and torque generated at pump startup. • Reservoir debris can affect the operation of the pump.	• Could cause potential increases in summer downstream water temperatures. • The placement of the pump could affect the location of the floating barrier upstream of the dam.	• Not likely – would require renting a large pump/surface aerator capable of moving large volumes of water.

Ranking	Technology	General Description	Anticipated Costs	Potential Benefits	General Disadvantages	Project Suitability	Testing Capacity
●	Infuser weir	• A low-head concrete structure built across a tailrace, typically 2-5 feet high. The weir has transverse slots in the top of it and flow drops into the hollow concrete structure and water is passed through slots in the downstream face.	• Design, engineering, and installation of weir • Maintenance, clearing debris from the weir • Some loss of revenue due to lost head.	• If available free head, can produce large increases in DO (5+ mg/L), requires no power to operate.	• Capital costs can be high and the performance of the weir can be difficult to predict. • Weirs are non-navigable and can block fish movement. • Weirs also reduce the net head at hydroelectric projects by increasing the tailwater elevation	• Revenue could decrease due to lost head. • NYPA staff mentioned maintenance would be a concern. • Increasing the tailwater at the powerhouse by 2 – 5 feet could overtop the lower platform at the downstream end of the powerhouse.	• No. Even if modeled, impacts on DO could be difficult to predict.
■	Submerged tailrace diffusers	• Air-supplied diffuser arrays anchored in the tailrace, supplied by compressed air systems on the stream bank.	• Installation and maintenance of the diffuser system • Increased energy expenditure for compressed air and diffuser system • Diffusers can last between 8 – 10 years. • Compressors require yearly maintenance and periodic overhauls. • Possible expansion of the installed system due to low transfer efficiencies	• Diffusers are widely accepted aeration devices.	• Low aeration efficiencies can occur in tailwater depths less than 15 feet. • Initial capital and maintenance costs can be high. • Some systems can require large tailwater areas to be effective. • Oxygen systems take up less area but oxygen must be stored on-site in tanks along with vaporizers. • Noise suppressing systems might be needed. • Air injection systems are not recommended for tailwaters with high dissolved nitrogen content.	• It isn't clear at this stage whether the tailrace enclosed by the current floating barrier would provide enough area for a diffuser system to make up for the DO deficit at Jarvis.	• Not likely – would require purchasing diffusers to test.
■	Turbine venting (aerating runner)	• Air is introduced into the turbine via a specially designed runner. Ports or hollow bucket blades release air into areas with naturally lower pressures eliminating the need for compressed air injection.	• Design, engineering, and installation of new runner	• System operates well over broad operational range. • High levels of DO uptake are possible. • Efficiency losses are reduced compared to baffle or other air injection methods. • System can be shut down during high DO periods and not reduce turbine efficiency.	• Initial development costs are high. • Costs can be reduced by installing new runner when major runner maintenance has already been scheduled.	• Installing aerating runners in Francis-type units is far more common than for Kaplan units.	• No – the turbine runners aren't going to be replaced for testing purposes.
■	Turbine venting (vacuum breaker)	• Air passage through turbine head cover with exit ports on the turbine hub. Hub baffles can be used to increase suction.	• Potential design, engineering, and installation costs for re-sizing of the vacuum breaker system. • Potential increased turbine maintenance costs due to increases in cavitation.	• This method can typically be tested with existing (or modified) structures. • No moving parts • No power supply needed • No effect on discharge temperature	• Oxygen uptake potential is limited. • Performance is difficult to predict. • This type of venting has been associated with increases in cavitation damage on turbine equipment including damage to runners and/or bearings. • Generation output can be reduced. • Venting Kaplan style turbines is not common.	• The units don't have vacuum breakers.	• No – the units don't have vacuum breakers.

Ranking	Technology	General Description	Anticipated Costs	Potential Benefits	General Disadvantages	Project Suitability	Testing Capacity
	Selective withdrawal	• Withdrawal of water from reservoir depths where DO and temperature may be desirable. • Structures used to accomplish selective withdrawal include wet wells and submerged weirs.	• N/A	• Potential design, engineering, and installation costs for re-sizing of the vacuum breaker system. • Potential increased turbine maintenance costs due to increases in cavitation.	• Temperatures of the water in the epilimnetic zone may be detrimental to downstream fisheries. • Retrofitting for selective withdrawal can be costly. • This technology is inappropriate for sites with large reservoir level fluctuations and navigation projects.	• The intake and penstock are fixed in place. Capital costs to adjust the location of the powerhouse intake zone could be prohibitive. • The project doesn't spill often and the ogee spillway doesn't have any gates to control flow releases from higher elevations.	• No – the infrastructure needed to adjust the withdrawal zone at the Project doesn't exist and would be costly to construct.
	Reservoir destratification	• Using mechanical pumps or compressed air systems at the deepest point in the reservoir to mix and break down the chemical and thermal stratification that contributes to hypolimnetic DO depletion.	• Design, engineering, installation and operation of the mixing equipment.	• Design, engineering, and installation of the selective withdrawal system	• May result in negative effects on reservoir fisheries by changing habitat characteristics. • This method may disturb reservoir sediments and may not result in measurable increases in DO. • Energy requirements for this method can be prohibitive.	• Safety measures would need to be added to protect recreationists from structures in the middle of the reservoir. • Higher DO concentrations near intake could increase fish entrainment.	• N/A.
	Hypolimnion aeration	• Aeration via a submerged system of diffusers anchored at the bottom of a reservoir.	• Design, engineering, installation, and operation of the aeration system.	• This technology is typically considered for storage/peaking impoundments (> 3,000 acre-ft.) with cold water fisheries. • Reservoir water quality can benefit through oxidation of hydrogen sulfide and dissolved iron.	• Not considered suitable for large run-of-river projects where the system would have to be sized for the maximum powerhouse hydraulic capacity. • Estimates of hypolimnetic oxygen demand and oxidation rates are needed. • The most significant cost item can be buying pure oxygen.	• Could affect reservoir fisheries. • Higher DO concentrations near intake elevations could increase fish entrainment. • May not have long enough contact time for oxygen absorption.	• N/A
	Reservoir water quality management	• Reduction of point and non-point sources for organic matter and nutrients entering the reservoir to prevent eutrophication.	• Costs to work with the surrounding community and implement Best Management Practices (BMPs).		• Reducing point and non-point sources beyond what current standards require can be costly and additional measures may not lead to measurable increases in DO in hydropower releases.	• Low DO at intake elevation is due to reservoir stratification caused by its depth not an overabundance of nutrients and plant activity. • Watershed is predominantly undeveloped so there is little opportunity to increase DO by reducing nutrients loads. • NYPA would have to work with others within the 373 square mile drainage area and improvements to DO concentrations in the reservoir and tailrace could be limited.	• N/A

2.1 Recommended Technologies

The Power Authority reviewed the findings of the Literature Review and decided to further study the feasibility of surface aerators/fountains, penstock gas injection, and automating the 60” sluice gate (Gate No. 4).

3 Feasibility Analyses

The information gathered during the literature search was used to determine the feasibility of the three selected DO enhancement technologies for the Project taking into account site-specific details. Existing Project engineering drawings and product literature were used to inform the feasibility analyses and to develop preliminary opinions of probable construction costs (OPCCs).

3.1 Surface Aeration Technologies

3.1.1 System Configuration

Fountain and Surface Aerator System Configuration

Floating fountains and surface aeration devices consist of plastic/metal fabricated pieces floated into place or installed by boat on a lake or pond. Typically, floating fountain/aerators are anchored to the bottom of a lake or pond bed using concrete blocks or they are attached to shore with cables. Installing cables across the tailrace could be a potential safety risk for NYPA staff performing maintenance tasks. Figure 3.1.1-1 and Figure 3.1.1-2 show examples of what typical aerating fountains and surface aerator units may look like and additional information is provided in Appendix B and Appendix C respectively.

Electrical cords can be provided in lengths up to 1,000 feet. The cords connect the fountains to an approximately 13.5” x 14.5” NEMA (National Electrical Manufacturers Association) 4X enclosure with device controls. Typically, the electrical cords are trenched above the water line to the location of the controls.

Figure 3.1.1-1 Aerating Fountains[8]

Figure 3.1.1-2 Surface Aerators[9]

[8] Image sources: 1) www.kascomarine.com, 2) www.otterbine.com
[9] Image sources: 1) www.kascomarine.com, 2) www.otterbine.com

Aspirating Aerators Configuration

Aspirating aerators consist of motorized propeller devices which typically float on the surface of the water on a set of metal or plastic pontoons or are attached to a structure with a metal arm. These aerators are typically installed at wastewater treatment plants and in aqua-culture businesses. Figure 3.1.1-3 shows an example of what typical units may look like and a brochure with supporting literature on these devices is provided in Appendix D.

Above the water is a motor attached to an arm extending below the water surface with a propeller below the water surface. The arm is hollow with an opening/port above the water surface (manufacturers refer to the arm as a draft tube). As the propeller spins and pushes water away it creates a vacuum within the arm/draft tube and air is drawn in. As air is drawn in, it is pulled downward through the draft tube and is mixed with the water below the water surface as the propeller spins.

Figure 3.1.1-3 Aspirating Aerators[10]

3.1.2 Project Suitability

There are a wide variety of fountains, surface aerators, and aspirating aerators available. Based on a review of available technology, aspirating aerators have the most powerful motors and are able to transfer much more oxygen per unit than the other technologies. Characteristics of the aerating fountains, surface aerators, and aspirating aerators reviewed are presented in Table 3.1.2.-1 below.

[10] Image sources: 1) www.fluencecorp.com, 2) www.fluencecorp.com

Table 3.1.2-1. Required Surface Aerator Configuration[11]

Technology	Horsepower (HP)	Oxygen Transfer (lb/HP HR)	Max. Oxygen Transferred Per Unit (lb/HR)
Aerating Fountain	1/2 – 1	0.8 – 2.2	2.2
Surface Aerator	1 – 5	2.3-3.3	16.5
Aspirating Aerator	10 -100	2.0	200.0

The number of aerating units that would be needed over the range of Project discharges was determined based on the calculations on pages 6-47 – 6-49 of Appendix E and the equations below. The equations ultimately determine the horsepower required to transfer enough oxygen into the tailrace to meet state standards.

Step 1 – Determine oxygen demand in the tailrace

$$Oxygen\ Demand\ \left(\frac{lb}{min}\right) = Project\ Discharge\ (cfs) \times \frac{28.32\ Liters}{Cubic\ Feet} \times \frac{60\ s}{min} \times Oxygen\ Deficit\ \left(\frac{mg}{L}\right) \times \frac{1\ lb}{454{,}000\ mg}$$

Table 3.1.2-2. Predicted Tailrace Oxygen Demand Based on Project Discharge

Powerhouse Discharge (cfs)	Oxygen Deficit (mg/L)	Oxygen Demand (lb/min)
300	2.4	2.69
600	2.4	5.38
900	2.4	8.08
1800	2.4	16.16

Step 2 – Determine Oxygen Transfer Rate in the tailrace when DO deficit is the greatest (2.4 mg/L)

$$N = N_0 \times \left(\frac{((C_{walt} \times CF) - C_L)}{9.1}\right) \times (1.024)^{T-20}$$

Where:

[11] Surface aerator characteristics based on the High Volume Industrial Aerator by Otterbine Barebo Inc, https://www.otterbine.com/aerators-fountains/industrial-pond-aerators-circulator/high-volume/ .

N = oxygen transfer rate in tailrace (lb O_2/HP-HR)
N_0 = oxygen transfer rate (aerator unit manufacturer rate) (lb O_2/HP-HR)
C_{walt} = DO saturation of water at a given altitude (mg/L) (See Appendix E)[12]
CF = Oxygen solubility correction factor based on altitude[13]
C_L = Operating DO concentration (mg/L)
T = Tailrace Water Temperature (Degrees Celsius)

Table 3.1.2-3. Oxygen Transfer Rate Factors

	C_L	N	N_0[14]	C_{walt}	CF[15]	T[16]
Max. Oxygen Transfer Rate	3.6	1.31	2.3	9.651	0.95	17
Min. Oxygen Transfer Rate	6.0	0.75	2.0	9.651	0.95	17

Depending on the DO concentration of the water passing through the powerhouse, the oxygen transfer rate in the tailrace varies between 0.75 lb O_2/ (HP-HR) and 1.31 lb O_2/ (HP-HR). For the purposes of these calculations, both transfer rates were used to determine an approximate range for the horsepower required at the Project when the dissolved oxygen deficit in the tailrace is the greatest versus when the tailrace dissolved oxygen concentration deficit approaches zero.

Step 3 – Determine the horsepower required to transfer enough oxygen to meet the demand.

$$HP\ (Req'd) = \left[Oxygen\ Demand\ (from\ Step\ 1)\left(lb\frac{O_2}{min}\right)\times 60\left(\frac{min}{HR}\right)\right] \div Avg\ Oxygen\ Transfer\ Rate\ (from\ Step\ 2)(lb\ O_2/(HP-HR)$$

The number of fountains, surface aerators, and aspirating aerator units required to make up for the oxygen deficit in the tailrace based on a range of project discharges is compared in Table 3.1.2-4. The number of aspirating aerators required to increase DO concentrations in the tailrace is much lower than the number of aerating fountains or surface aerators due to the available range in horsepower for aspirating aerators, which have ratings between 10 and 100 HP. It is estimated between 2 and 15 aspirating aerators (depending on their size) would be required to make up a

[12] The project altitude falls in the 1000 – 1500 foot range provided in the table of values for C_{Walt} correction values in Table G-3 from Appendix E.
[13] See Table G-1 in Appendix E.
[14] The documentation in the manufacturer literature indicates the units can supply up to 3.3 lb/HP-HR of oxygen but a separate manufacturer has specifications for similar units which only guarantee up to 2.3 lb/HP-HR (https://kascomarine.com/product/surface-aerators/). Based on ASE 1991 report aspirating aerators have transfer rates of approximately 2 lb/HP-HR.
[15] Oxygen solubility correction factor applied to the DO saturation value based on Table G-1 in Appendix E.
[16] Average temperature from tailrace temperature monitoring between June and September 2018 and July – September 2019.

2.4 mg/L oxygen deficit in the tailrace when the powerhouse is discharging 300 cubic feet per second (cfs) with an existing tailrace DO concentration of 3.6 mg/L.

Table 3.1.2-4. Required Aspirating Aerator Configuration[17]

Powerhouse Discharge (cfs)	Oxygen Deficit (mg/L)	Oxygen Demand (lb/min)	Horsepower Required (HP)[18]	No. of Aerating Fountains Required (1 HP)	No. of Surface Aerators Required (5 HP)	No. of Aspirating Aerators Required (100 HP)
300	2.4	2.69	123 – 249	123 – 249	25 – 50	2 – 3
600	2.4	5.38	247 – 499	247 – 449	50 – 100	3 – 5
900	2.4	8.08	370 – 748	370 – 748	74 – 150	4 – 8
1800	2.4	16.16	740 – 1496	740 - 1496	148 - 300	8 - 15

It is worth noting that surface aerating devices (including fountains) are not typically installed in moving bodies of water because low aeration efficiencies can occur in tailwater depths less than 15 feet due to short residence times. Therefore, the efficiencies advertised by the manufacturers may be lower in a tailrace installation and consequentially, the number of aerating devices required for the project may be greater than the values presented in Table 3.1.2-4 above. The Otterbine Barebo Inc. pond management guide in Appendix F recommends installing one 1-3 HP fountains or surface aerator per acre of water surface. There is no guidance in the document for unit spacing in riverine environments.

The documentation in Appendix E recommends maintaining 10 feet between individual 10 HP aspirating aerator units and 30 feet between 100 HP units to avoid mixing aeration plumes which could reduce oxygen transfer rates. This means that each 10 HP unit requires at least 400 square feet of surface area (20’ x 20’) and 100 HP units require up to 3600 square feet (60’ x 60’). The worst-case scenario of an oxygen deficit of 2.4 mg/L at the maximum project discharge of 1,800 cfs would require 150 10 HP units encompassing approximately 60,000 square feet or fifteen 100 HP units requiring approximately 54,000 square feet for the minimum oxygen transfer rates in Table 3.1.2-3. Either is larger than the Jarvis tailrace area of 9,100 square feet; therefore, these units would not be suitable if designed for a powerhouse discharge of 1,800 cfs. Figure 3.1.2-1 below shows the approximate size of the Jarvis tailrace.

[17] Maximum horsepower units for each technology were selected.
[18] The horsepower required range varies due to the range of potential oxygen transfer rates in the Project tailrace.

Figure 3.1.2-1 Project Tailrace Schematic

3.1.3 Costs

Aerating Fountain and Surface Aerator Capital Costs

Each 1 HP aerating fountain costs approximately $3,000 (including a 200 foot long power cable), excluding shipping and installation. The cost of just the fountains could range between $369,000 for 123 fountains to increase DO concentrations for a generation flow of 300 cfs to over $4.4 million dollars for 1,496 1 HP units required for a generation flow of 1,800 cfs.

Each 5 HP surface aerator unit (including a 200 foot power cable) costs approximately $8,000 to purchase excluding shipping and installation. The cost of just the aerators could range between $200,000 for 25 aerators to increase DO concentrations for a generation flow of 300 cfs to over $2.4 million dollars for 300 5 HP units for a generation flow of 1,800 cfs. Other capital costs to consider are trenching for the electrical cords, installation of device anchors, and installation of the control panels.

The electrical/operation costs associated with the aerators would also need to be considered. Some aerators can be installed with small solar panels to provide the power for operation. It is unclear at this time where solar panels could be installed at the site or if they would be compatible with the units specified in Table 3.1.2-4 above.

Aspirating Aerator Capital Costs

Aspirating aerators cost between approximately $10,000[19] and $31,000[20] for 10 and 100 HP units respectively excluding shipping and installation. The cost of just the aerators could range between $62,000 for two 100 HP aerators to enhance DO concentrations for a generation flow of 300 cfs to $465,000 for 15 100 HP units for a generation flow of 1,800 cfs. Other capital costs to consider are providing electrical service and anchoring the units.

Electrical cords are typically purchased separately.

Maintenance Costs

Any floating aerator devices would need to be removed for winterization and re-installed prior to summer/low-DO months. It is recommended that the devices be inspected every year and the oil must be changed every three years. Because high capital costs cause surface aeration technologies to be cost prohibitive, the maintenance costs for these technologies were not determined.

3.2 Penstock Gas (Air/Oxygen) Injection

3.2.1 System Configuration

Air or oxygen is injected into a penstock through existing or installed ports where it is mixed in with the water conveyed through a powerhouse. Based on various field studies, the volume of air injected into the penstock/turbine flow is proportional to the increase in dissolved oxygen concentration (i.e. 1% air produces an increase of 1 mg/L).

Air injection systems require compressors and hoses to inject air into the penstock. Oxygen systems, by comparison, require approximately 1/5th of the air volume that compressed air systems do while accomplishing the same goal. The downside to injecting pure oxygen systems is having to maintain a constant supply of oxygen on-site, which presents additional safety hazards to consider.

3.2.2 Project Suitability

Literature indicates that gas injection is appropriate for deficits of 1-2 mg/L, but for deficits greater than or equal to 3 mg/L, gas injection may need to be paired with another mitigation strategy. Based on the maximum observed dissolved oxygen deficit of approximately 2.4 mg/L, a volume of compressed air equal to approximately 2.4% of the turbine flow would need to be injected into the penstock (Black and Davis. 2002). Based on powerhouse flows of 300 – 1,800 cfs during low

[19] Price source provided in Appendix D – Tornado 10 HP aspirating aerator.
[20] Quote for 100 HP aspirating aerator provided in Appendix D from FluenceCorp.com provided on November 4, 2020.

DO periods, the volume of compressed air required for injection would vary between approximately 7.2 cfs (432 cubic feet per minute (CFM)) to 43.2 cfs (2,600 CFM). The combination of air compressors was selected to provide a range of air flows which would provide flexibility for the Project over a range of generation flows. The air compressors required would need to overcome approximately 58 feet of static head (approximately 27 psi) at the intake to inject air into the penstock.

The only existing vent or port upstream of the turbine in the penstock are two existing 12" diameter steel vents at the intake. The vents are currently used to supply air into the penstock when it is dewatered or filled. Proposed air injection systems utilizing these vents would need to consider the potential effects on the penstock filling/dewatering operations. A majority of the penstock between the intake and powerhouse is concrete and covered by concrete and/or backfill. The next accessible portion of the penstock downstream of the intake is within the powerhouse just upstream of the turbines. Figure 3.2.2-1 and Figure 3.2.2-2 show the proposed alignment/location of the proposed compressors and hoses.

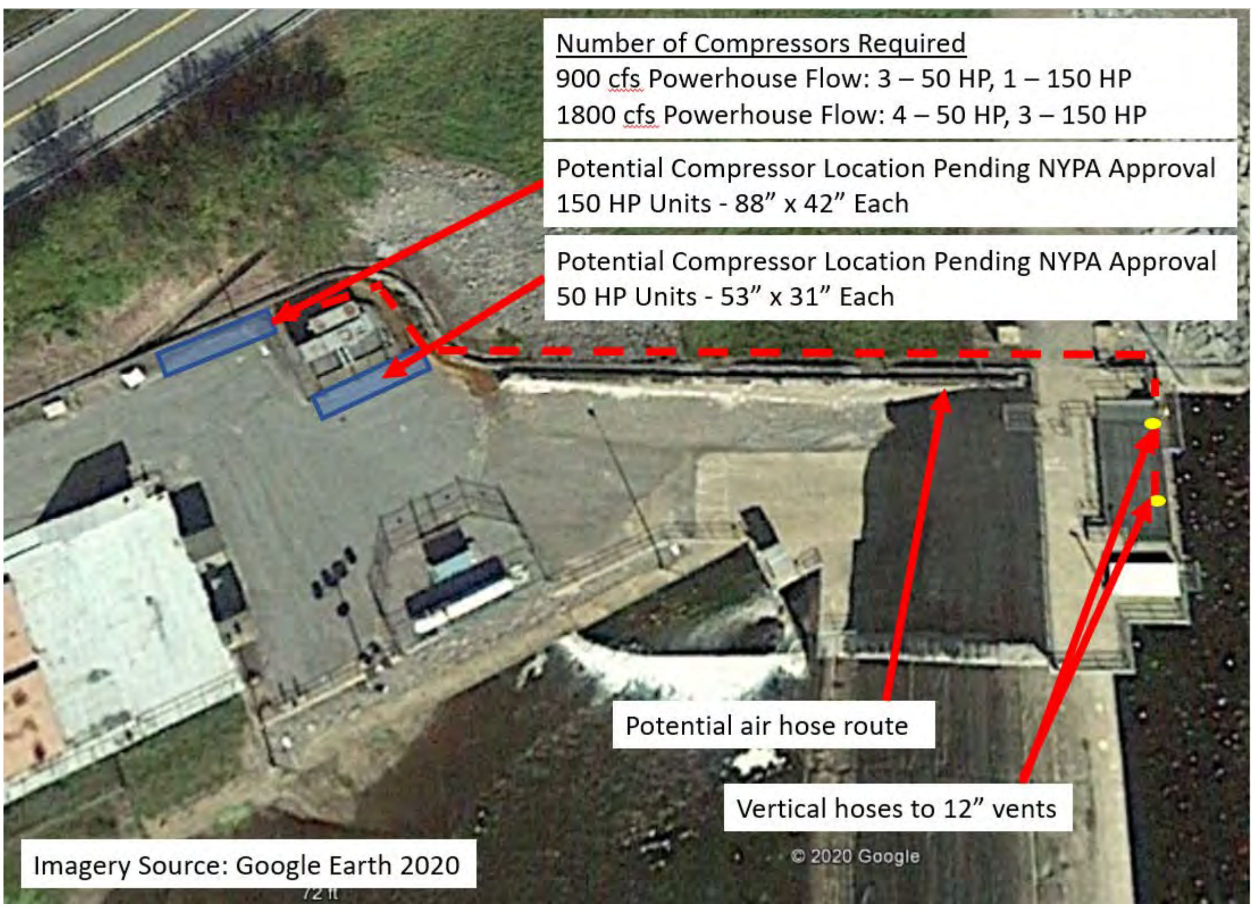


Figure 3.2.2-1 Penstock Air Injection Concept (Plan View)

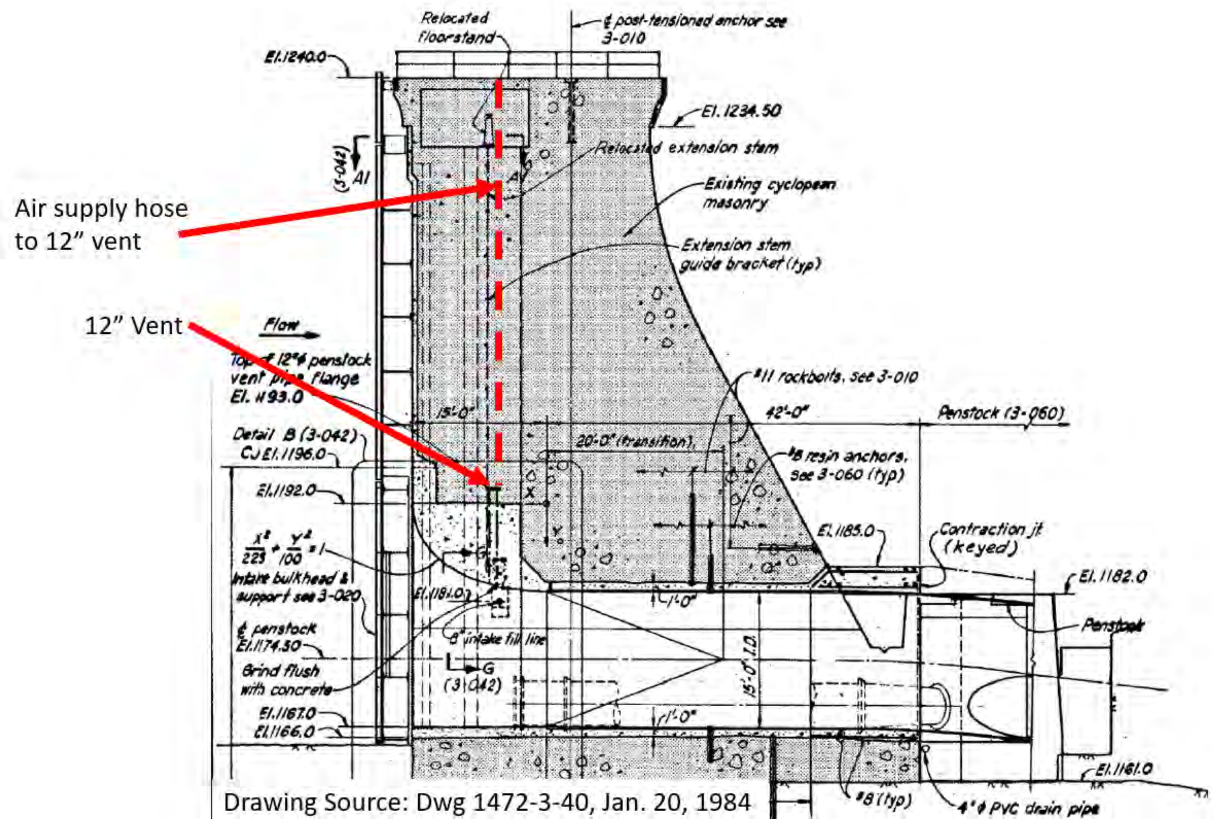


Figure 3.2.2-2 Penstock Air Injection Concept (Section View)

The potential impacts of penstock injection can be difficult to predict. Increased air/oxygen volumes in the penstock can result in cavitation and damage to the turbines and draft tubes. As a result, this dissolved oxygen mitigation technology may require more frequent turbine equipment refurbishment and shutdowns for maintenance. Sources recommended that turbine flow not exceed 4% air by volume.

3.2.3 Costs

An air injection system would require air compressor units and hoses to supply approximately 430 – 2,600 CFM of air through the 12" PVC vents (215 CFM – 1,300 CFM per vent) to increase tailrace DO concentrations between 300 and 1,800 cfs generation flows when the intake DO concentration is 3.6 mg/L. The approximate costs to install enough variable air flow compressors and hoses to increase dissolved oxygen concentrations for generation flows of 900 and 1800 cfs are $443,000 and $766,000,[21] respectively. The costs include installing air compressors outside

[21] A 40% contingency factor was included. This contingency was selected from Table 1 in the Association for the Advancement of Cost Engineering (AACE) Cost Estimate Classification System Recommended Practice 18R-97. The actual costs of these alternatives may vary from the OPCCs provided in this report.

the powerhouse and installing air hoses to the existing 12” penstock vents - those costs are presented in more detail in Appendix G. In addition to the equipment installation, the costs to operate the compressors should be considered.

Turbine Maintenance Impacts

The potential impacts that additional air injected into the penstock could have on the turbine should be investigated further. Additional air flow may increase the potential for cavitation and increase the frequency of repairs due to cavitation with periodic costs of up to approximately $50,000 per unit per repair and turbine shutdowns.

3.3 Gate No. 4 Operation

3.3.1 System Configuration

The existing 60” sluice gate is located at the bottom of the right non-overflow section on the upstream side of the dam. The outlet draws water from the reservoir at a similar elevation as the powerhouse but the outlet freely discharges into the tailrace. Tailrace DO concentrations can be improved with the mixing of low DO water from the turbine intake with higher DO water discharged from Gate No. 4.

The existing 60” sluice gate just downstream of the stoplogs is referred to as Gate No. 4. The gate itself is currently manually operated by on-site personnel with an electro-mechanical operator, which was replaced in 1997. The existing gate operator is accessible from a control room above the gate at elevation 1232.11. Currently the gate support frame is broken at the bottom and it is estimated that the discharge through the bottom of the frame is approximately 20 cfs which discharges into the tailrace through the outlet pipe.

3.3.2 Project Suitability

Gate No. 4 Testing

On August 7, 2019, field testing of Gate No. 4 was performed to determine the reaeration potential from Gate No. 4 releases while generating. The results of this testing were included as Appendix A to the Study Plan filed for this study with FERC on December 20, 2019. Testing entailed measuring the tailrace DO concentration for different combinations of discharge from one turbine and Gate No. 4. Turbine discharges varied between 300 and 900 cfs and Gate No. 4 releases varied between 20 and 540 cfs. These combinations resulted in total discharges or reservoir releases ranging between 320 and 1,440 cfs.

Prior to testing, a vertical dissolved oxygen and temperature profile of Hinckley Reservoir was taken on August 6, the day before testing. The data indicated that the reservoir was stratified – DO at the top of the intake (1192 ft) was 7.18 mg/L and at the bottom of the intake (1167 ft) was 2.14 mg/L. The average DO concentration in the reservoir at elevations ranging between the top and bottom of intake was 4.27 mg/L and the average water temperature was 20.9 °C. A spot check at the installation of the logger below Gate No. 4 on August 6 showed a water temperature of 19.0 °C and a DO concentration of 8.35 mg/L. The tailrace spot check showed a slightly higher water temp of 20.5 °C and a DO of 4.54 mg/L, 0.27 mg/L higher than the average DO at the intake.

On August 7, 2019, the tailrace DO was measured for varying turbine and Gate No.4 discharges. All Gate No. 4 DO measurements throughout the testing were near 8.0 mg/L (between 90 and 99% saturation). The results demonstrated that DO enhancement is possible when the turbines are operating if Gate No. 4 releases are provided. The magnitude of releases from Gate No. 4 required to achieve DO enhancement to New York State (NYS) water quality standards is proportional to turbine discharge volume and the stratification condition in Hinckley Reservoir and can be computed using the following mass balance equation.

$$Tailrace\ DO = \frac{(Turbine\ cfs\ x\ Turbine\ DO) + (Gate\ No.4\ cfs\ x\ Gate\ No.4\ DO)}{Turbine\ cfs + Gate\ No.4\ cfs}$$

<u>Effect of Gate No. 4 Releases on Generation</u>

The Project can generate power when reservoir releases are at least 300 cfs, the minimum hydraulic capacity of one turbine. When releases are less than 300 cfs, the reservoir release is provided by opening Gate No. 4 and this release also meets the daily average daily minimum DO standard of 6.0 mg/L downstream of the tailrace.

Since there are an infinite number of combinations of intake DO and turbine discharges that could be studied using Gate No. 4 for DO enhancement, a range of combinations was examined to assess the impact on Project generation. The mass balance equation can be rearranged to solve for what the Gate No. 4 discharge should be based on the average daily DO standard concentration (6 mg/L), turbine discharge, and turbine DO concentration:

$$Gate\ No.4\ cfs = \frac{(Turbine\ cfs)(Tailrace\ DO - Turbine\ DO)}{Gate\ No.4\ DO - Tailrace\ DO}$$

This is illustrated in the following example with a turbine discharge of 300 cfs, turbine DO concentration of 5 mg/L, and Gate No. 4 DO concentration of 8 mg/L which results in a No. 4 gate discharge of 150 cfs to meet the average daily DO concentration of 6 mg/L at the tailrace.

$$Gate\ No.4\ cfs = \frac{(300\ cfs)(6\frac{mg}{L} - 5\frac{mg}{L})}{8\frac{mg}{L} - 6\frac{mg}{L}} = 150\ cfs$$

Based on the Gate No. 4 testing, it is assumed that the Gate No. 4 DO concentration will be 8 mg/L regardless of discharge. Two different cases were assumed for the intake DO, one close to the standard, 5.5 mg/L resulting in a DO deficit of 0.5 mg/L and the other, a low intake DO of 3.6 mg/L which results in a DO deficit of 2.4 mg/L. If the DO deficit is small, less water needs to be discharged through Gate No. 4 to mix with turbine water to meet the stream DO standard of 6 mg/L. For example, if the generation flow is 300 cfs, the Gate No. 4 discharge needs to be 75 cfs when the turbine intake DO concentration is 5.5 mg/L to achieve a tailrace DO concentration. This results in a total reservoir release of 375 cfs. Conversely for an intake DO concentration of 3.6 mg/L[22], the Gate No. 4 discharge needs to be 330 cfs resulting in a total reservoir release of 660 cfs. This means if reservoir releases are less than 660 cfs and the intake DO is 3.6 mg/L, the Project cannot generate and the reservoir release will be provided entirely by Gate No.4[23]. The relationship between powerhouse discharge from one turbine for intake DO concentrations of 5.5 mg/L and 3.6 mg/L over the range of Gate No. 4 releases required to achieve a daily standard DO concentration of 6.0 mg/L downstream of the tailrace is provided in Table 3.3.2-1 below.

[22] Lowest measurement of tailrace DO concentration recorded during 2018 and 2019
[23] The flow from the units would be limited by the discharge capacity of Gate No. 4.

Table 3.3.2-1. Powerhouse and Gate No. 4 Releases Required to Achieve State DO Standards

Powerhouse Discharge (cfs)	Required Gate No. 4 Discharge (cfs) if intake DO=5.5 mg/L	Total Discharge (cfs) if intake DO = 5.5 mg/L	Required Gate No. 4 Discharge (cfs) if intake DO =3.6 mg/L	Total Discharge (cfs) if intake DO=3.6 mg/L
300	75	375	360	660
450	112	562	540	990
600	150	750	720	1320
900	225	1125	1080	1980

Some of the combined discharges through Gate No. 4 and the turbine when the intake DO is 3.6 mg/L exceed the reservoir releases stipulated by the 2012 Operating Diagram during the months of June to September when low DO concentrations can occur. The reservoir release or total discharge is limited to 1400 cfs until Hinckley Reservoir water levels are higher than El. 1226 which is unlikely during the June to September time period.

The required flows from the Table 3.3.2-1 above were compared to the monthly flow duration curves for Project outflow previously developed for the Final License Application (FLA)[24]. Table 3.3.2-2 provides the corresponding outflow exceedances for the range of potential project outflows for the months from June to September, if Gate No. 4 is used to achieve a daily DO standard of 6.0 mg/L downstream of the tailrace. This analysis indicates that reservoir releases are often less than what is required to meet downstream stream standards while generating. For example, based on flow availability and the mass balance equation, sufficient reservoir releases in July for generation and Gate No. 4 discharge would be limited to approximately between 24% and 3% of the time for powerhouse discharges between 300 and 900 cfs respectively when the intake DO is 3.6 mg/L. When the intake DO is higher such as 5.5 mg/L, the range is 92% and 12% for generation flow between 300 and 900 cfs.

[24] Outflow flow duration values were based on July 2001 – December 2019 data.

Table 3.3.2-2. Required Gate No. 4 Release

Project Discharge (Powerhouse Discharge) Flow Duration								
Month	Intake DO = 5.5 mg/L				Intake DO = 3.6 mg/L			
	375 cfs (300 cfs)	562 cfs (450 cfs)	750 cfs (600 cfs)	1125 cfs (900 cfs)	660 cfs (300 cfs)	990 cfs (450 cfs)	1320 cfs (600 cfs)	1980 cfs (900 cfs)
June	93%	70%	33%	21%	39%	25%	18%	4%
July	92%	49%	18%	12%	24%	13%	9%	3%
August	85%	42%	18%	4%	30%	5%	3%	1%
September	78%	54%	22%	2%	39%	3%	1%	1%

The flow exceedances in Table 3.3.2-2 indicate the Project would have a limited ability to generate during low DO months if Gate No. 4 is used to improve tailwater water quality. In addition, the need to use Gate No. 4 discharges to mix with low intake DO water may affect the ability of the project to peak when intake DO concentrations are low.

As a comparison, the historical operations data in the Peaking Fluctuations Study Report, prepared in 2019, indicated that in 2018 the Project peaked for 47 days between June 1 and September 30. In June 2018, peaking flows ranged from 570 to 760 cfs. The project peaked 23 days in June and 24 days in September and did not peak in July and only once in August. Typically, in 2018, Project outflows were closer to 340 cfs which would only be high enough to operate Gate No. 4 when intake DO is less than the stream standard to maintain DO standards.

Estimate of Lost Generation by Using Gate No 4 for DO Enhancement

Using outflow exceedance values for the Project, the potential impacts on annual generation were reviewed using Project outflow duration data. The analysis compared the effects of gate operation on average monthly generation assuming that the turbine intake DO concentration was 3.6 mg/L. The following equation was used to determine the generation at the site for a given outflow[25]:

$$Gen.(MWH) = \frac{Flow\ (cfs)\ x\ Head\ (ft)\ x\ (Turbine/Generator)\ Efficiency}{11.8} \div 1000\frac{kw}{MW}\ x\ 24\ \frac{hr}{day}\ x\ \frac{Days}{Month}$$

It should be noted that the maximum generation/powerhouse discharge for the proposed analysis

[25] The model assumed a constant head of approximately 54.2 feet as measured in SCADA data obtained for June – October 2018 and an overall efficiency of 90%.

was capped by the maximum discharge capacity of Gate No. 4 as determined by the orifice equation:

$$Q_{Orifice} = C_d \ x \ A \ x \sqrt{(2gh}$$

Where:

Q = orifice discharge capacity (cfs)
C_d = coefficient of discharge, typically 0.62[26]
A = Area of orifice entrance (square feet, sf)[27]
g = Gravity (ft/s^2)
h = Head (reservoir surface elev. – centerline of orifice elevation, ft)

Based on the orifice equation above, the capacity of Gate No. 4 was estimated using the maximum, minimum, and average observed 2018 reservoir elevations based on data obtained from the SCADA system as shown in Table 3.3.2-3.

Table 3.3.2-3. Estimated Gate No. 4 Discharge Capacity

Reservoir Elevation (ft, BCD)	Orifice Centerline (ft, BCD)	Gross Head (ft)	Max. Discharge (cfs)
1225	1169.5	55.5	466
1214	1169.5	44.5	417
1195	1169.5	25.5	315

For the proposed conditions with Gate No. 4 used for DO enhancement, generation was limited by the discharge capacity of Gate No. 4, approximately 417 cfs, which is based on the average reservoir elevation of 1214 ft, BCD, observed in 2018. A Gate No. 4 discharge of 417 cfs corresponds to a powerhouse discharge of 348 cfs to maintain New York State daily average DO concentrations in the tailrace when intake DO is 3.6 mg/L based on the mass balance equations described previously. Generation estimates were capped at a generation flow of 348 cfs.

The results of this generation analyses are presented in Table 3.3.2-4.

[26] The orifice discharge coefficient is based on a sharp-edged entrance coefficient as compared to a more efficient sharp-tube entrance coefficient of 0.82 as prescribed in the Civil Engineering Reference Manual for the PE Exam by Michael Lindeberg, (2014 - Fourteenth Edition).
[27] The diameter of the sluice gate/conduit is five feet while the diameter of the gate valve is four feet. There is a reducer and expansion on either side of the gate valve. The orifice area was based on the four foot gate valve diameter.

Table 3.3.2-4. Average Project Generation During Low DO Months (2010 – 2019)

Month	Existing (MWH)	Existing (Spreadsheet Model) (MWH)	Proposed Gate No. 4 Operations (MWH)	Generation Reduction (MWH)	Ratio (Proposed/Existing) (%)
June	2,226	2,146	378	1,768	17.6%
July	1,858	1,823	243	1,580	13.3%
August	1,352	1,519	297	1,221	19.6%
September	1,559	1,461	375	1,086	25.7%

To check the accuracy of this approach, the generation results from existing conditions were compared to the average Project generation reported in the Final License Application for the months of June through September from 2010 - 2019. The model results were deemed close enough (within 6% +/- on average) to assess the effect of Gate No.4 releases on generation. The existing conditions analysis assumes a constant release of 20 cfs from Gate No. 4 which represents leakage. The proposed/ modified Gate No. 4 operation analysis assumes that the turbine intake DO is 3.6 mg/L and therefore the turbine flow and flow required from Gate No. 4 can be computed based on the total flow.

Assuming that the turbine intake DO concentration was 3.6 mg/, the analysis indicates that operating Gate No. 4 continuously to maintain the DO stream standard could result in reducing generation between approximately 13.3% and 25.7% between June and September. The actual lost generation will likely be less than this because it is expected that the DO deficit will not be 2.4 mg/L throughout the 4-month period from June to September based on observed data in 2018 and 2019. A copy of the generation spreadsheets for the analysis are included in Appendix H.

3.3.3 Costs

Capital

The use of Gate No. 4 for increasing dissolved oxygen concentrations in the Project tailrace could be accomplished by either manually opening the existing 60” sluice gate as NYPA currently does or by replacement of the existing gate with one with automatic controls. Either alternative would require a real-time dissolved oxygen monitor to be installed in the tailrace and at the intake to determine when and how much the gate would need to be opened.

The capital cost for manual operation is just the cost of two real-time dissolved oxygen monitors. Capital costs for the gate replacement would include selective demolition of the existing 60” gate and the fabrication, delivery, and installation of a new 60” gate. It is anticipated that the gaskets at the flange connections between the existing pipe and the replacement gate would be replaced along with the gate.

Two actuation/operator systems were investigated for the replacement gate operator including a hydraulic power unit (HPU) or an electrical operator. A hydraulic power unit (HPU) could be installed to power the valve or to connect the new gate to an existing HPU. There doesn't appear to be an HPU nearby based on a review of the Project drawings. An HPU would require oil to operate and could present an environmental risk if an oil leak were to occur in the gatehouse and if oil made its way to West Canada Creek. Based on the limited space available and potential environmental risk of an HPU, an electric gate actuation was selected.

It is assumed that power would need to be provided from an electrical source in the vicinity of the powerhouse. Costs to connect the existing supervisory control and data acquisition (SCADA) system and to install a surveillance and warning system for Gate No. 4 releases were also included in the OPCC. The OPCC for the replacement of Gate No. 4 with an automated gate is $439,000, as shown in Appendix I. In Appendix J, there is a conceptual sketch that shows the location of the sluice gate being replaced.

3.4 Real-Time Dissolved Oxygen Monitoring Costs

An additional capital cost to any of the three dissolved oxygen mitigation alternatives described above would be the installation of a permanent DO monitor in the Project tailrace. Currently there is no real-time monitoring of dissolved oxygen at the Project. The monitoring device would be connected to the SCADA system and allow for the new gate to open and close as required based on tailrace and intake DO concentrations and flows. Alternatives for providing continuous dissolved oxygen monitoring equipment were investigated. The capital cost for purchasing two permanent DO monitors can vary between $20,000 – $70,000. Discussions with dissolved oxygen monitoring equipment vendors did not indicate specific life spans for their products. However, vendors noted that the components within the cabinet which would be pulled in the winter such as the telemetry unit and data logger have been known to last up to 20 years prior to replacement. The solar panels/batteries for the system are typically replaced more frequently than that but vendors did not offer a particular replacement frequency for those components. Over the duration of a 40-year FERC license, permanent real-time dissolved oxygen equipment would need to be purchased twice assuming a life span of 20 years.

Costs for renting and purchasing monitoring equipment are compared in Table 3.4-1 below and product literature is provided in Appendix K.

Table 3.4-1. Dissolved Oxygen Monitoring Equipment Alternatives (per monitoring location)

Fondriest Rental (per Month)	Fondriest (Buoy)	YSI Turnkey Systems (streamside)	YSI Turnkey Systems (buoy)
$4,000	$10,000	$15,000 – 20,000	$25,000 – $35,000

Note that these costs only account for the buoy/float and real-time monitoring device/service. Anchor and cable costs are not included. It is anticipated that depending on the location the buoy could be anchored with a heavy-duty rope or plastic-coated cable connected to cinder blocks.

O&M

The dissolved oxygen monitoring equipment would be installed and removed (or returned to the rental company) annually to protect it from high flows over the winter. The 16 “D” batteries in the monitoring probe were reported by the manufacturer to last several months.

Streamside alternatives offered by YSI may be prone to less damage or less likely to get washed away during high flow events compared to a buoy system . A streamside installation would be easier to service compared to a buoy system since it would be performed on-shore without a boat. The streamside setup would include a small cabinet housing a data logger and associated telemetry equipment. During periods where dissolved oxygen monitoring isn’t required (i.e. winter) the data logger and telemetry equipment could be removed from the cabinet or left inside it year-round.

4 Summary and Conclusions

The main purpose of the study was to evaluate alternatives for increasing dissolved oxygen concentrations in the Jarvis Project tailrace to meet NYS water quality standards. Specific objectives of the study were to perform a literature review of potential strategies and assess the feasibility of three dissolved oxygen enhancement methods. The alternatives were prioritized based on a review of Project drawings and discussions with Power Authority staff. As a result, the three alternatives selected for additional investigation were surface aeration in the tailrace, air injection into the penstock, and utilization of Gate No. 4 releases.

Several tailrace surface aeration techniques were investigated including the installation of surface aerators, aerating fountains, and aspirating aerators. Typically, many of these units are installed in waters without a current such as lakes or ponds. Due to flow conditions in the tailrace, oxygen transfer rates may be unpredictable and the overall performance of these units is difficult to predict. In addition, due to the minimum space required between units to maximize oxygen transfer rates, there is not enough space in the Project tailrace alone to install enough devices to address the Project dissolved oxygen deficit. The project tailrace immediately downstream of the powerhouse only has a surface area of approximately 9,100 square feet and approximately 54,000 square feet would be required to install the fifteen 100 HP aspirating aerators required to mitigate low DO at the Project at a generation flow of 1,800 cfs (two turbines). The approximate capital costs for this alternative for generation flows of 900 cfs and 1,800 cfs are $248,000 and $465,000 respectively. Even if this alternative was limited to increasing flows for one turbine (900 cfs), the 28,800 square feet area requirement is far more than the 9,100 square feet in the tailrace, thus making this technology infeasible.

The second DO enhancement alternative was the injection of air into the penstock. The system would require air compressors outside the powerhouse supplying a total of between 430 – 2,600 CFM of air (2.4% of the overall flow) into the penstocks depending on the powerhouse discharge and DO deficit. Approximately 2” hoses would be connected to each compressor and fed through the existing penstock dewatering/filling vents. The capital costs for this alternative for generation flows of 900 cfs and 1,800 cfs is approximately $443,000 and $766,000 respectively. The details for how the air hoses from the compressors are fed through the existing penstock vents have not been worked out. Without additional modeling, the potential effects of increasing air flow within the penstock cannot be determined. It is anticipated that air injection may lead to increased cavitation and more frequent turbine repairs and shutdowns in the future.

The third alternative investigated was using Gate No. 4 releases to increase dissolved oxygen in the tailrace. Gate No. 4 would be opened to discharge the appropriate amount of flow to mix with turbine DO based on the mass balance relationship between the gate and turbine discharges and the real-time dissolved oxygen data. The results of testing and monitoring in August 2019 demonstrated that DO enhancement is possible when the turbines are operating if Gate No. 4 releases are provided. Replacing the existing 60-inch manually-controlled sluice gate with a 60-

inch automated sluice gate and real-time dissolved oxygen monitoring device would allow the Project to operate the gate to maximize DO from Gate No. 4 releases. However, based on the estimated discharge capacity of Gate No. 4 at a reservoir water level of 1214 ft BCD, the maximum powerhouse discharge would need to be capped at approximately 348 cfs to maintain the 6 mg/L NYS DO standard for large dissolved oxygen deficits (e.g. 2.4 mg/L). Lower summer flows, the Project's limited ability to peak, and the 2012 Operating Diagram would limit the ability for the Project to operate both Gate No. 4 and turbines to address large dissolved oxygen deficits. The capital cost for replacing the Gate No. 4 valve is approximately $439,000. A lower capital cost alternative for Gate No. 4 operation is to continue manual operation of Gate No.4 as needed to meet the DO standard in the tailrace; however, this would require significant operations and maintenance costs.. Utilizing Gate No. 4 releases could reduce generation between 13.3 and 25.7% of current monthly generation between June and September.

All DO enhancement technologies would require installation of real-time dissolved oxygen monitoring equipment in close proximity to the intake and also the tailrace so that the degree of DO enhancement was appropriate to address the DO deficit at the intake. The capital cost for installing permanent real-time dissolved oxygen monitoring equipment is approximately $10,000 - $35,000 per monitoring location ($20,000 - $70,000 for two) depending on the system. Over the duration of a 40-year FERC license, permanent real-time dissolved oxygen equipment would need to be purchased twice assuming a life span of 20 years.

The total capital costs for each alternative assume a DO deficit of 2.4 mg/L and flows up to 1,800 cfs for surface aeration and air injection and 900 cfs for Gate No. 4. The DO deficit could be higher than 2.4 mg/L at times and is likely variable during months when the reservoir DO stratifies, making it difficult to rely solely on one reaeration solution. It is also unlikely that generation flows during the summer months will be limited to the capacity of one unit (900 cfs) based on the specified releases from the 2012 Operating Diagram. If the capital cost for air injection is limited to one unit, the cost is closer to that of automating Gate No. 4. The capital cost of manual operation of Gate No. 4 is the lowest being only the cost of real-time dissolved oxygen monitoring equipment. If the Power Authority decides to pursue the use of Gate No.4 for DO enhancement, further consideration will be needed to decide whether it is cost effective to operate it manually or whether gate operation should be automated.

5 Literature Cited

Aquatic Systems Engineering. 1990. Assessment and Guide for Meeting Dissolved Oxygen Quality Standards for Hydroelectric Plant Discharges. Electric Power Research Institute. Palo Alto, CA: This report summarizes how to identify and address water quality issues at hydroelectric projects related to dissolved oxygen concentrations between project reservoirs and tailraces. Factors leading to low dissolved oxygen concentrations and impacts to nearby fisheries are described in detail. The report presents reservoir, forebay, turbine/powerhouse, and tailrace operational mitigation technologies for increasing dissolved oxygen content. For each potential technology/method to increase dissolved oxygen concentrations limitations, major obstacles to installation, environmental effects, expected equipment life expectancy, safety, possible failure modes, sizing, costs involved and case studies are presented.

Bevelhimer, M. S., and C. C. Coutant. 2006. Assessment of Dissolved Oxygen Mitigation at Hydropower Dams Using an Integrated Hydrodynamic/Water Quality/Fish Growth Model. Oak Ridge National Laboratory. Oak Ridge, TN. This paper describes a model which integrated water quality sampling data, fish growth data, and flow data to predict potential impacts of improvements made to the Center Hill hydroelectric project on the Caney Fork River in Tennessee. The model conducted three alternative analyses including a base case (observed conditions), potential aeration at the turbine (i.e. turbine venting, draft tube venting and air injection) and potential aeration improvements at the forebay (i.e. hypolimnetic aeration and forebay mixing). The initial modeling of the Center Hill Dam demonstrated that forebay mitigation measures could be counterproductive due to the increased temperature of the water discharged into the tailrace. Turbine venting was implemented at the dam and improved DO concentrations slightly, but based on field data collected, this measure alone did not prevent the DO concentrations from decreasing below 5 mg/L for a few weeks in the summer. The recorded increases in DO concentrations from various mitigation measures at several hydroelectric projects are presented in Tables 1 and 2 of the report.

Black, J. L., E. P. Taft, and D. A. Davis. 2002. Maintaining and Monitoring Dissolved Oxygen at Hydroelectric Projects. Electric Power Research Institute. Palo Alto, CA: This is an update of EPRI's 1990 report, "Assessment and Guide for Meeting Dissolved Oxygen Water Quality Standards for Hydroelectric Plant Discharges". Table 4-1 in Chapter 4 provides a summary table of technologies and their general advantages and disadvantages. Case studies of the technologies in the table mentioned above describe the results of the implementation of these mitigation measures. The study also includes a description of experimental technologies, including but not limited to U-tube aeration, downflow bubble contactors, and hollow fiber membranes. Chapter 4 also describes the recommended process for selecting the most appropriate technology and items to consider during the screening process through to implementation and maintenance.

March, P. A. 2013. Assessment of Aerating Hydroelectric Turbine Developments and Related Research Needs. Electric Power Research Institute. Palo Alto, CA: This report expands on the Hydropower Technology Roundup Report prepared in 2009. It provides an overview of aerating turbines for minimum and environmental flows, aerating Kaplan/propeller/diagonal flow turbines, an analyses of aerating Francis turbines, and environmental optimization of aerating turbines. Appendix A provides a list of hydroelectric projects where turbine aeration has been implemented. The report seems to indicate there are a limited number of sites with Kaplan units which have been customized for aeration purposes.

March, P. 2009. Hydropower Technology Roundup Report - technology Update on Aerating Turbines. Electric Power Research Institute. Palo Alto, CA: This study reviewed existing papers on topics between 1998 – 2009. The report summarizes the effects of different turbine aeration methods on turbine efficiencies. Turbine aeration methods discussed include central, peripheral and distributed systems. The central aeration method includes channeling air to the runner cone from an air intake located in the turbine head cover. Peripheral distribution includes injecting air below the runner via pipes. Distributed systems draw air through air intakes located in the head cover through turbine blades at the trailing edge of runner blades. There are charts in Section 5 which show central aeration of the turbine units was shown to reduce turbine efficiencies more than peripheral or distributed turbine aeration systems.

Mobley, M. 1997. TVA Reservoir Aeration Diffuser System, Technical Paper 97-3. Atlanta, GA. This report summarizes the aeration diffuser system development and implementation at six hydropower installations owned and operated by the Tennessee Valley Authority (TVA). The paper presents the costs and observed impacts on water, quality including dissolved oxygen and temperature.New York Power Authority (NYPA). 2019. Desktop Modeling of Peaking Fluctuations Study Report. Prepared by Gomez and Sullivan Engineers, D.P.C. White Plains, NY: Author. This report summarizes a desktop analysis on the effects of peaking operations on reservoir fluctuations at the project.

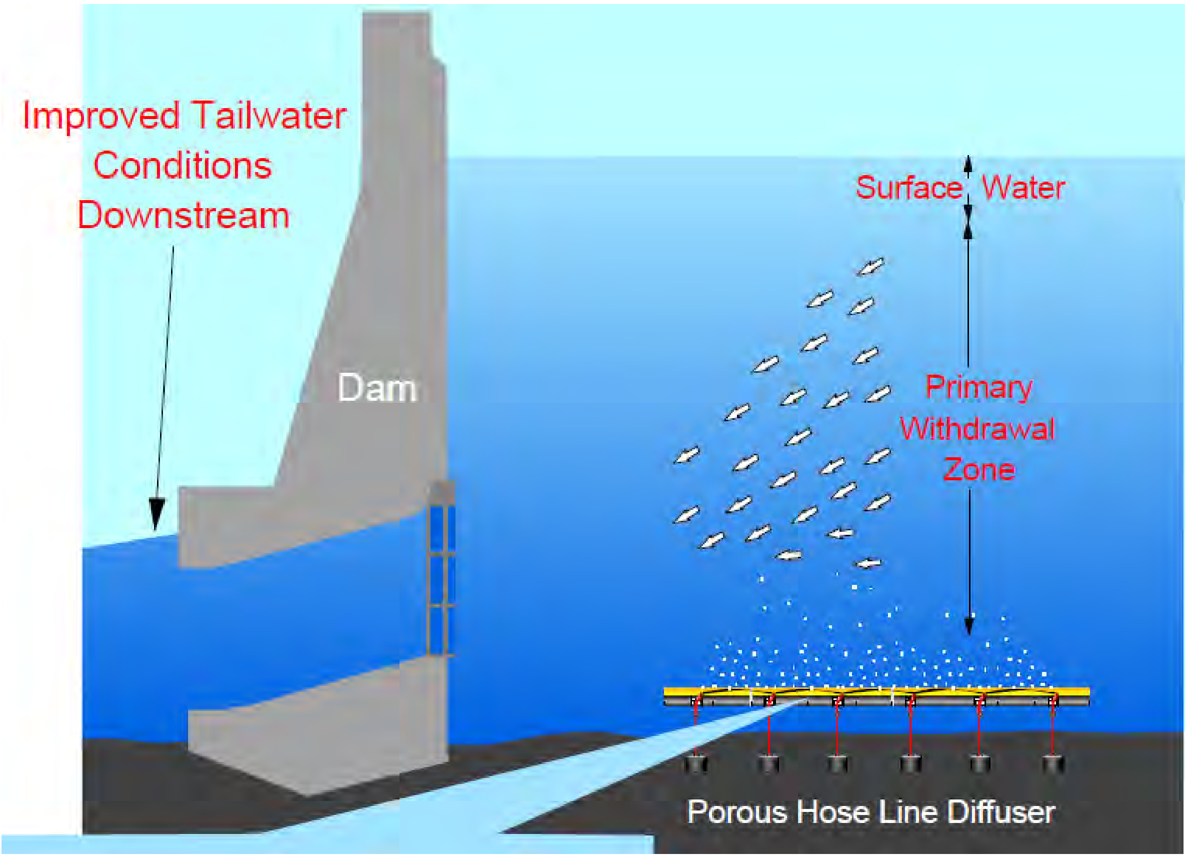
New York Power Authority (NYPA). 2018. 2018 Tailwater Water Quality Study. Prepared by Gomez and Sullivan Engineers, D.P.C. White Plains, NY: Author. This study summarizes the results of water quality monitoring in the Jarvis tailrace, including temperature, dissolved oxygen, and pH.

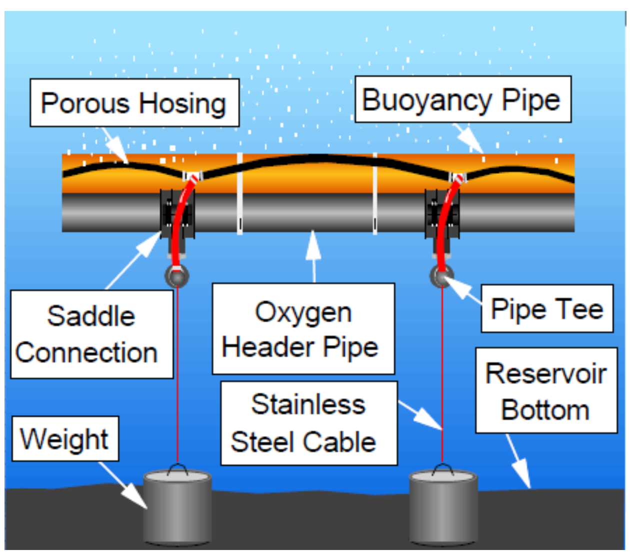
Sale, M. J., G. F. Cada, L. H. Chang, S. W. Christiensen, S. F. Railsback, J. E. Francfort, B. N. Rinehart, and G. L. Sommers. 1991. Environmental Mitigation at Hydroelectric Projects Volume 1. United States Department of Energy. Idaho Falls, ID. This report summarizes potential mitigation strategies for environmental impacts of hydroelectric projects. The report addresses instream flow, dissolved oxygen, and fish passage mitigation. Dissolved oxygen mitigation strategies are summarized in Table 3-2 and describes various technologies including general advantages, and general disadvantages. The study describes trends in environmental regulations and impacts by FERC region. The report described that of the 53 projects which provided information, 66% of the projects indicated that spill flows were utilized, 9% indicated intake control mitigation was used, 6% used reservoir improvements, 28% indicated turbine aeration was used, 6% used spray devices, and 11% indicated other methods were used (including tailrace

aeration weirs, intake aeration, reservoir destratification, and operational constraints). A combination of the technologies above were utilized at 25% of those projects.

Appendix A - Figures of Dissolved Oxygen Mitigation Strategies

Figure A.1 - Intake Aeration (air/oxygen injection)



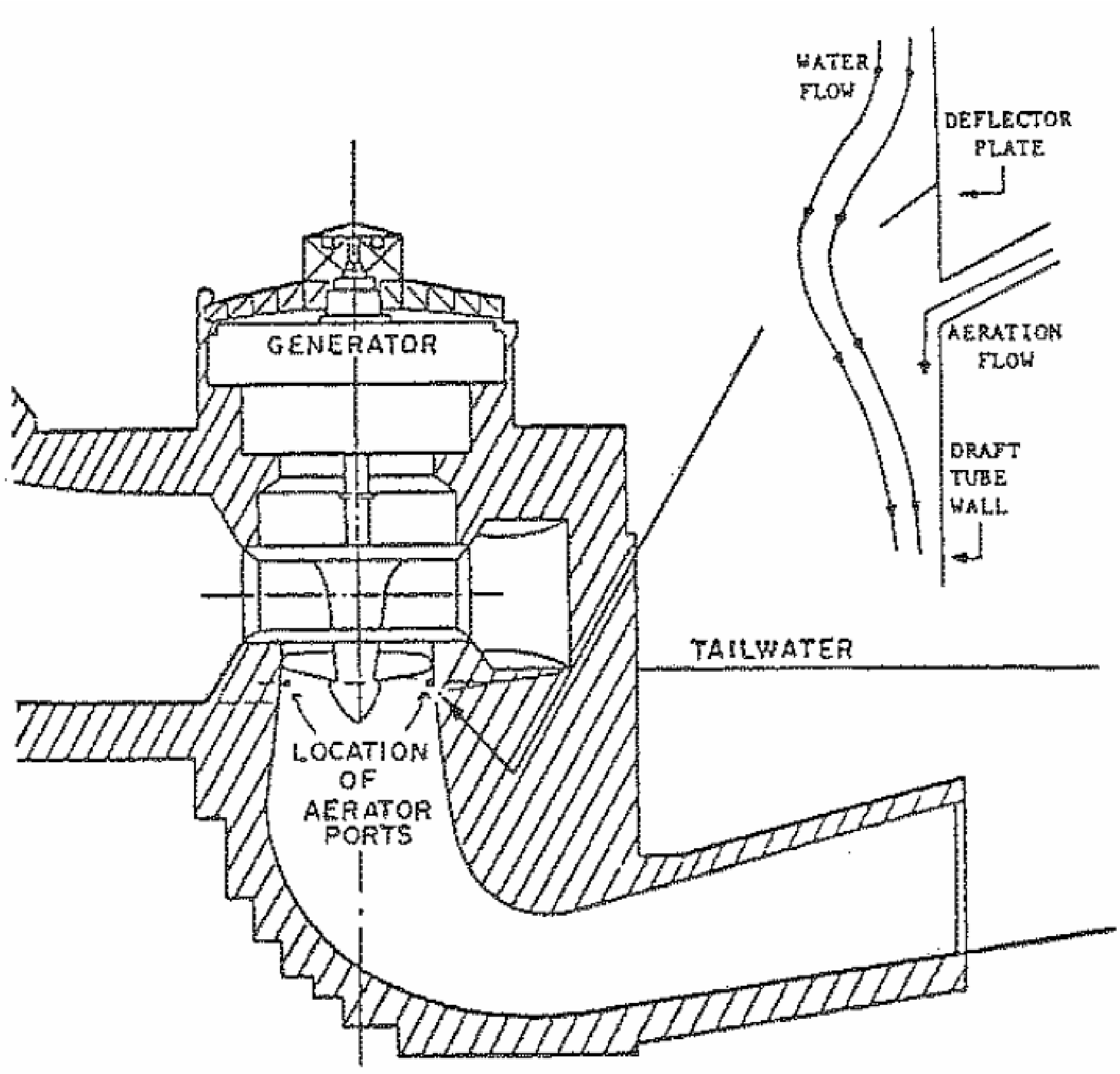


Source: Figure 2 (Mobley 1997).

Figure A.2 - Labyrinth Weir

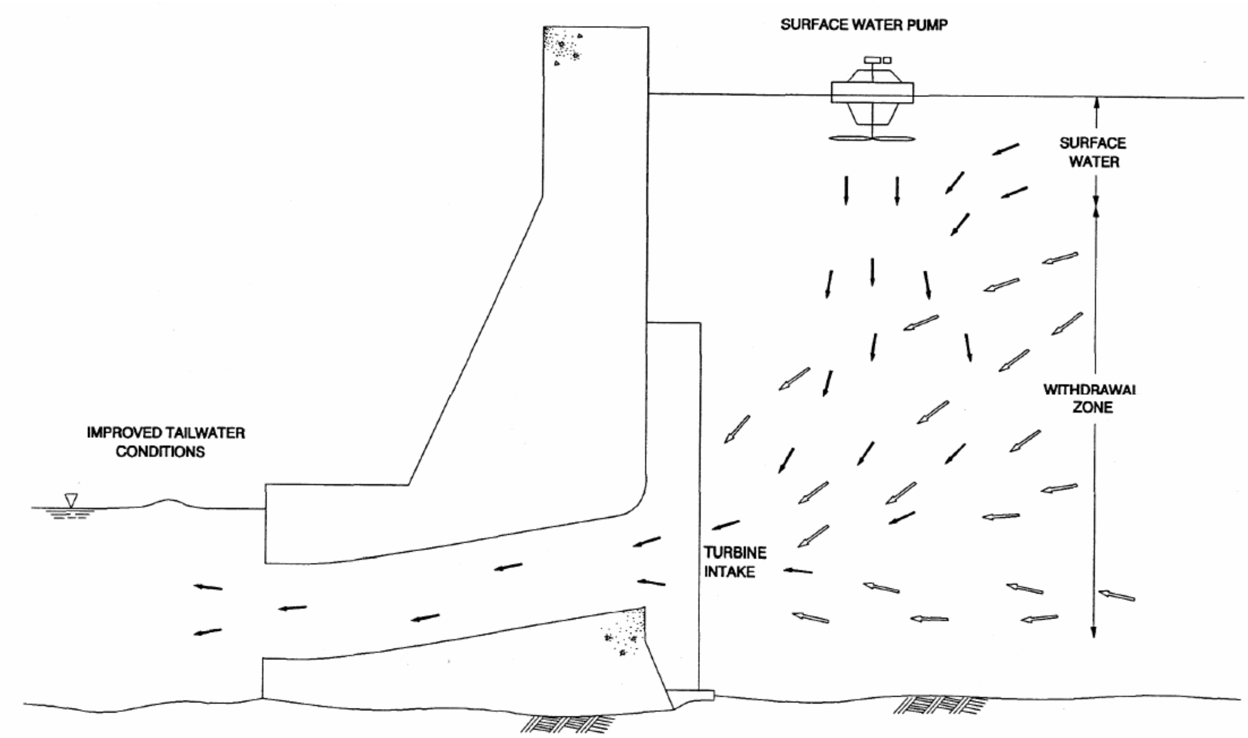
Source: Little York Dam (Gomez and Sullivan 2016).

Figure A.3 - Draft Tube Venting



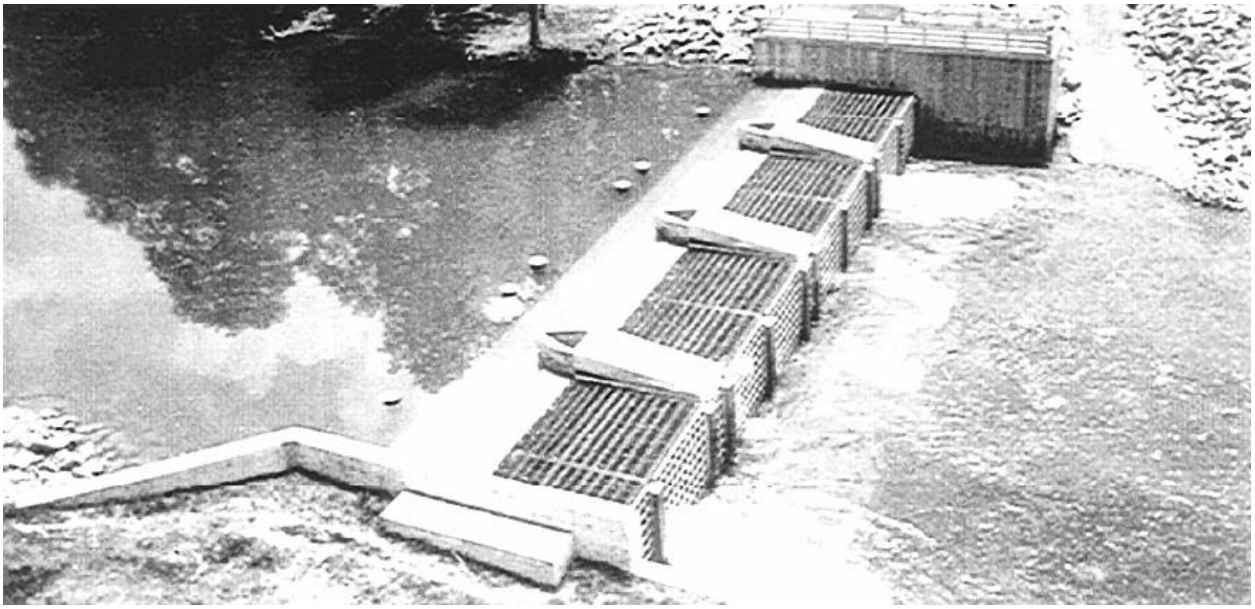
Source: Figure 4-30 (Black and Davis 2002).

Figure A.4 - Reservoir Epilimnion Pumps

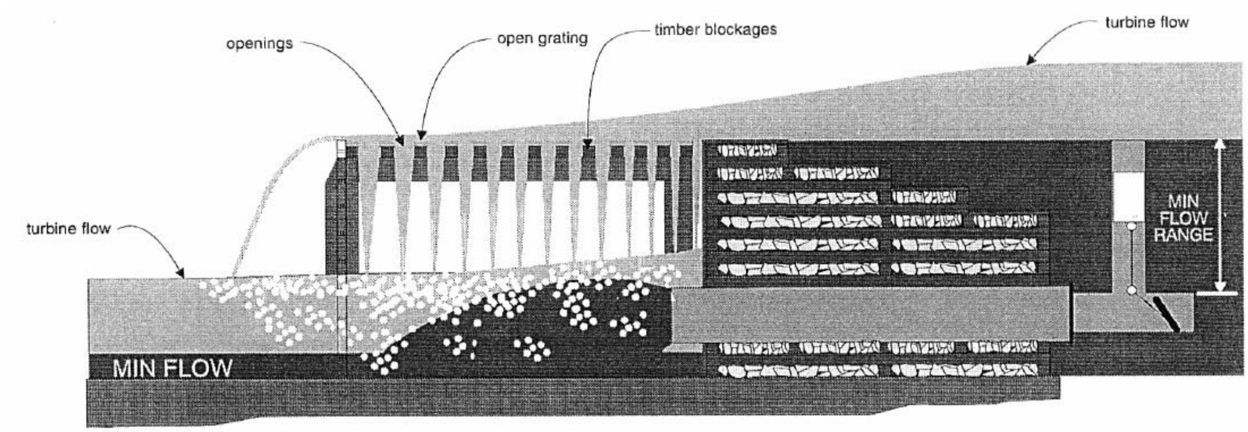


Source: Figure 4-14 (Black and Davis 2002).

Figure A.5 - Infuser Weir



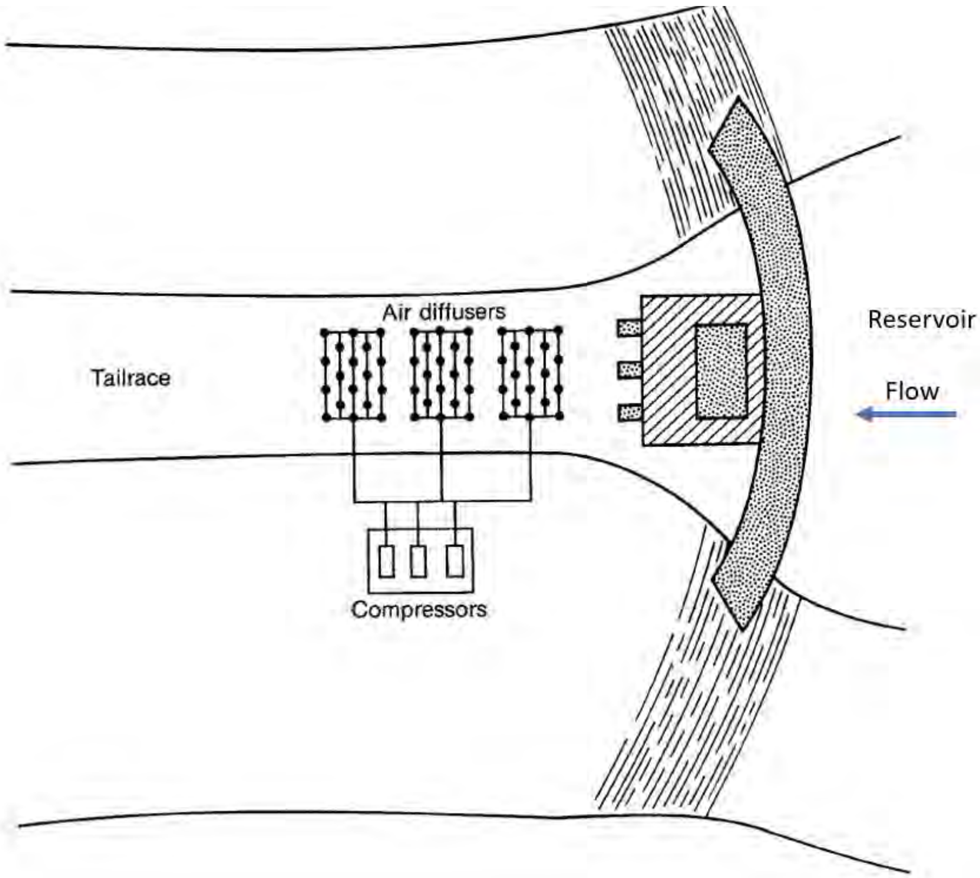
Source: Figure 4-4 (Black and Davis 2002).



Source: Figure 4-2 (Black and Davis 2002).

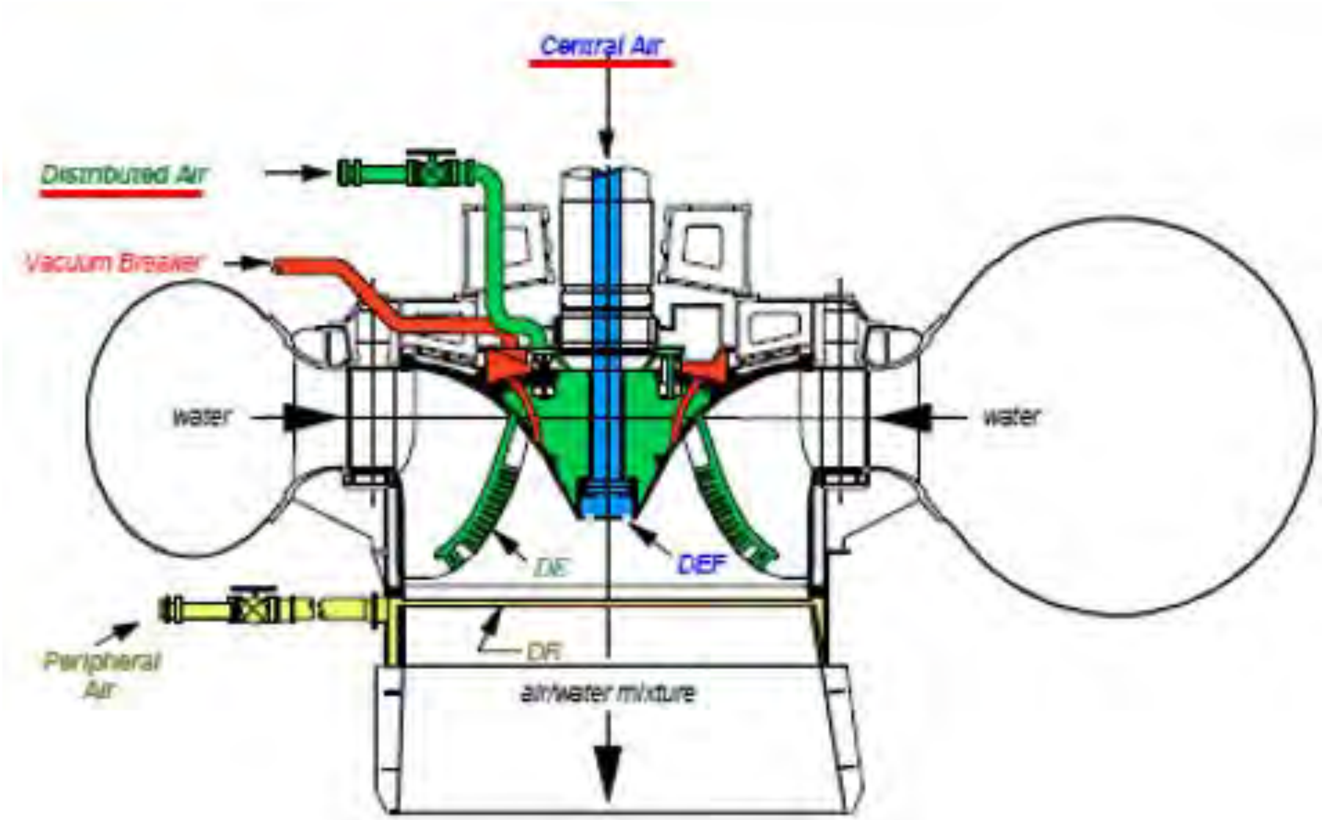
Figure A.6 - Submerged Tailrace Diffusers

Source (Kasco Marine Robust Aire Flyer 2020).



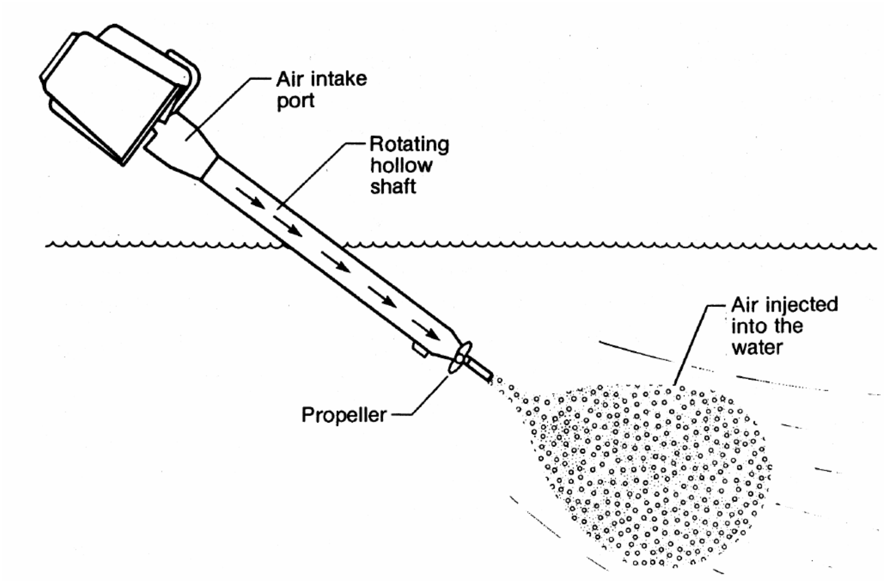
Source: Figure 6-6 (Aquatic Systems Engineering 1990).

Figure A.7 - Turbine Venting (aerating runner)



Source: Figure 1-1 (March 2009)

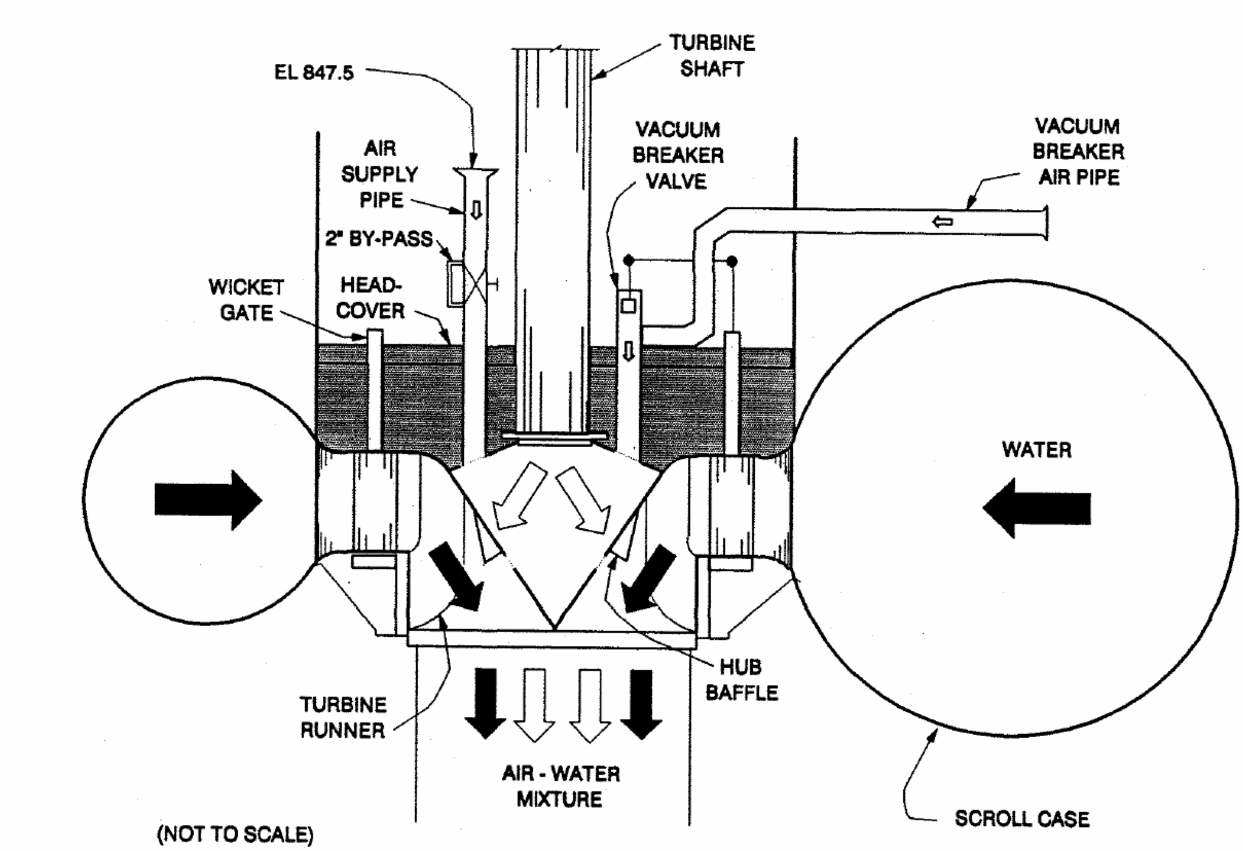
Figure A.8 - Surface Tailrace Aerators



Source: Figure 4-13 (Black and Davis 2002)

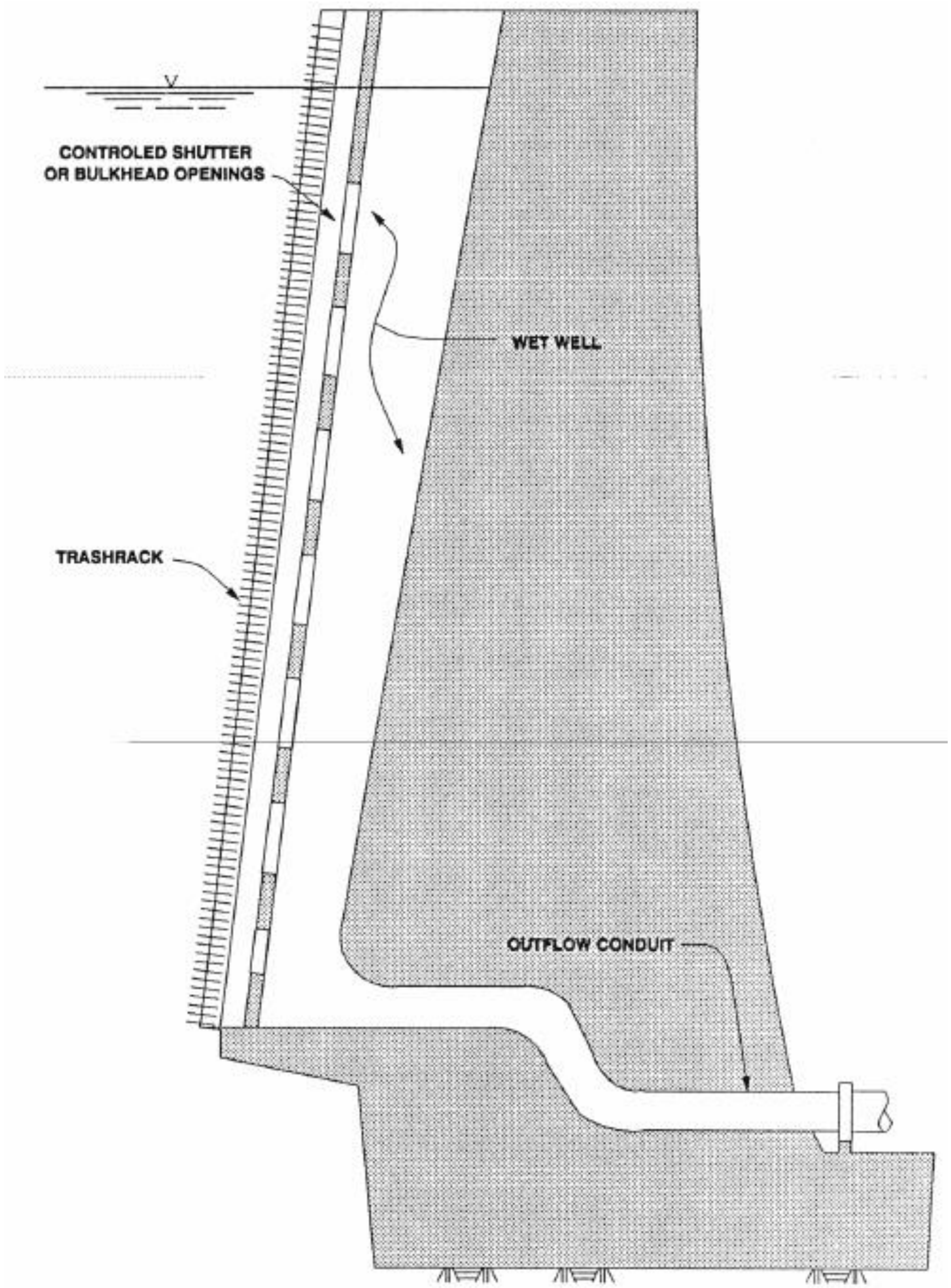
Source: https://kascomarine.com/product/surface-aerators/

Figure A.9 - Turbine Venting (Vacuum Breaker)



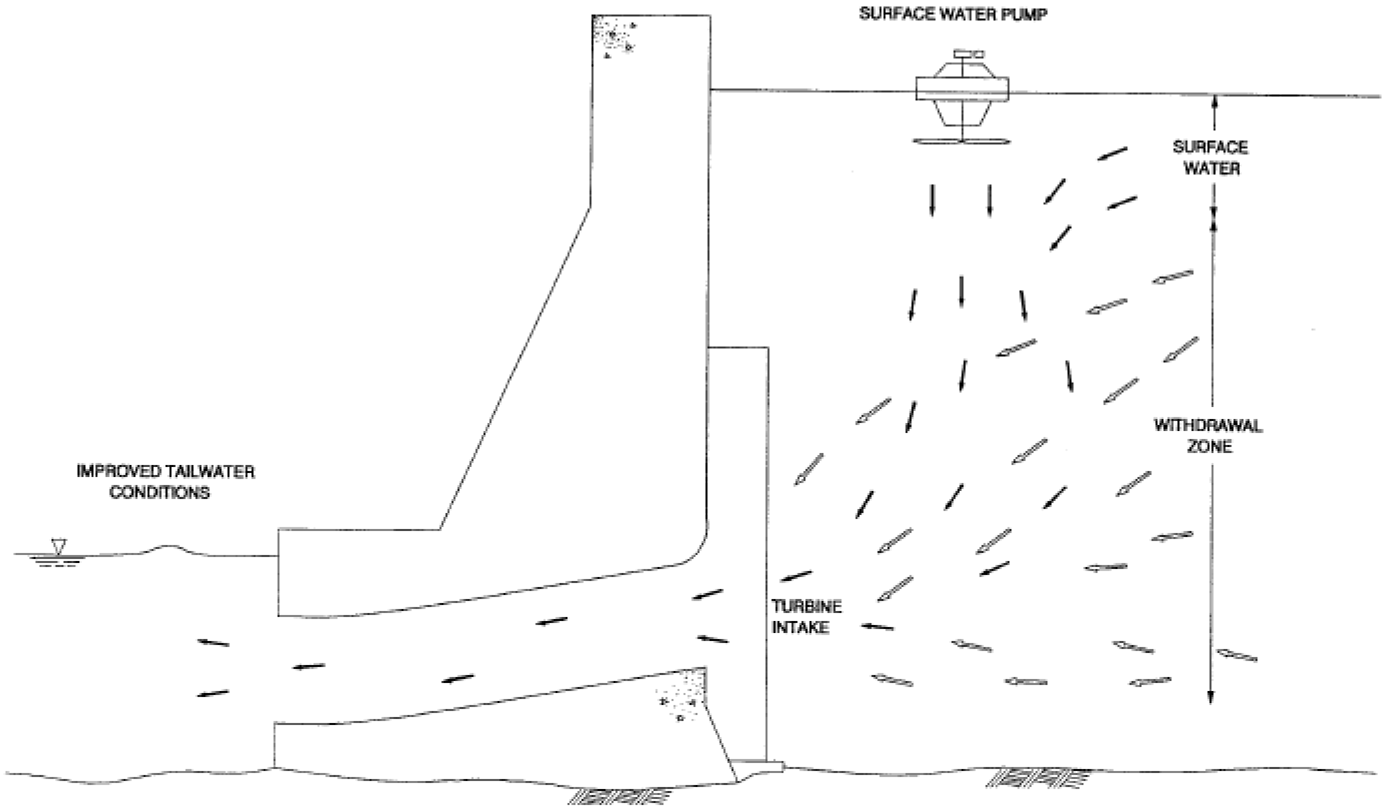
Source: Figure 4-31 (Black and Davis 2002).

Figure A.10 - Selective Withdrawal



Source: Figure 4-47 (Black and Davis 2002)

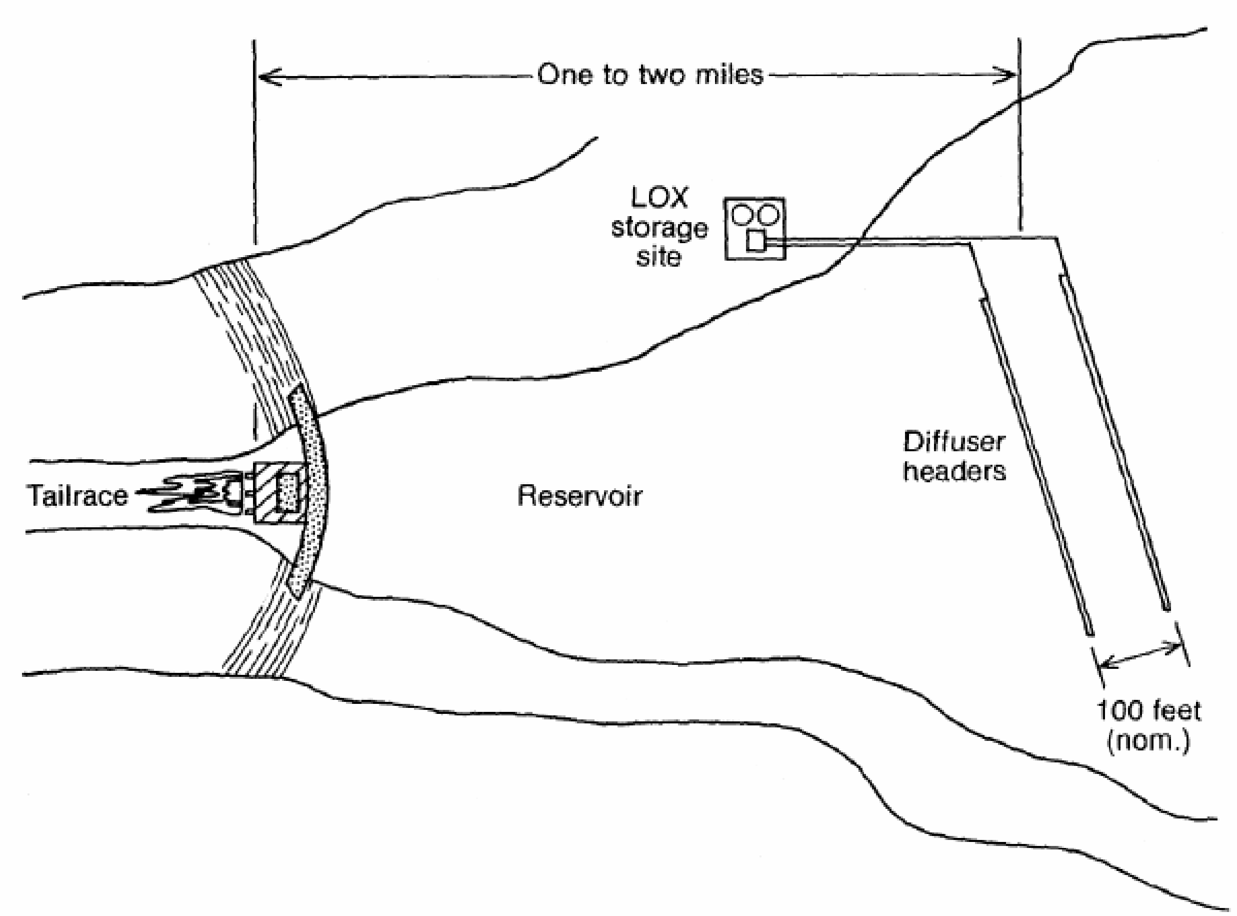
Figure A.11 - Reservoir Destratification



Source: Figure 6-15 (Aquatic Systems Engineering 1990)

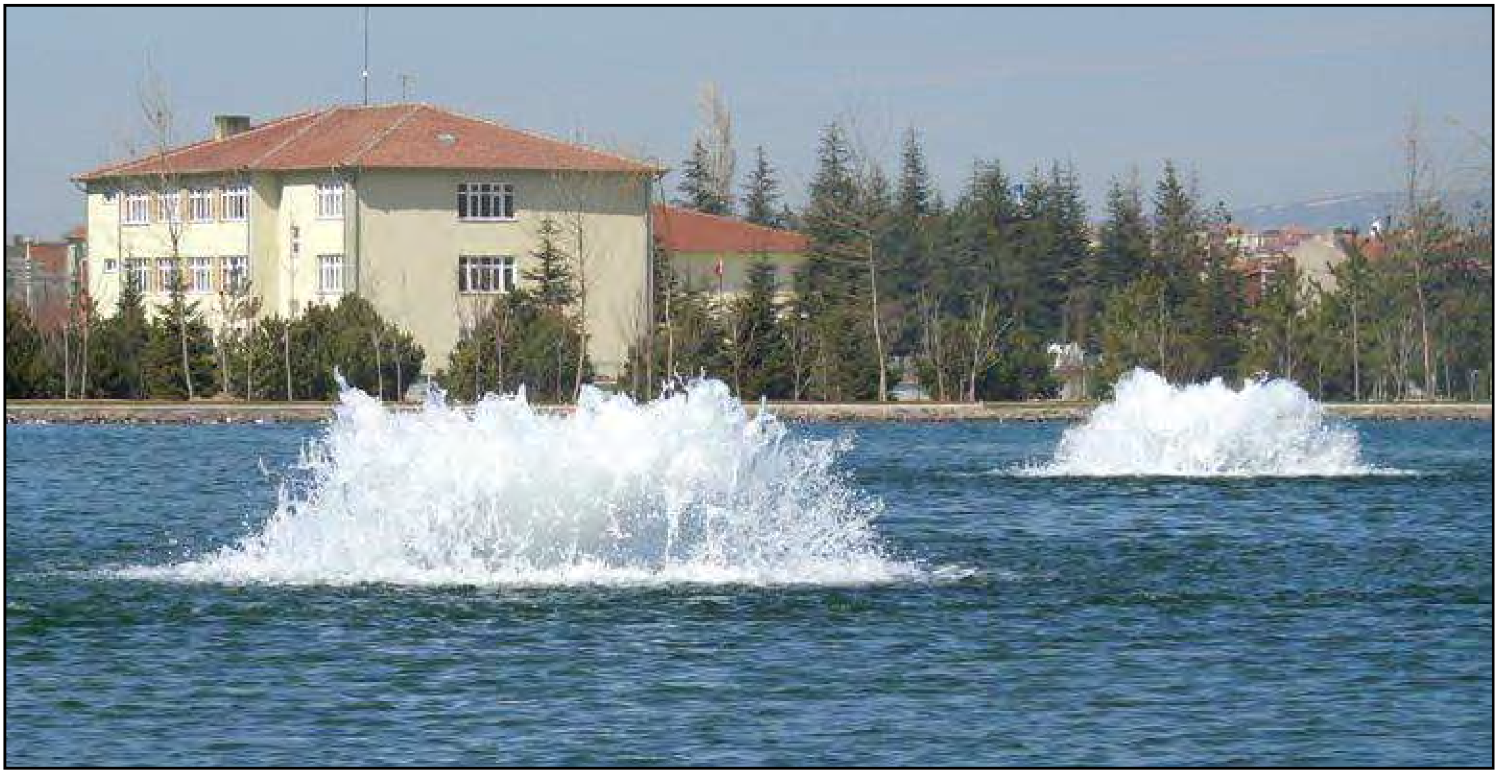
Source: http://mobleyengineering.com/technologies/hydropowerenhancements.html

Figure A.12 - Hypolimnion Aeration



Source: Figure 4-52 (Black and Davis 2002)

Appendix B - Surface Aerator Literature



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- Highest oxygen transfer and pumping rates in the industry, moving 3.3lbs or 1.5kg of oxygen per horsepower hour, and pumping over 900GPM or 198m^3/hr.
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- Power control center comes standard with surge arrestor, timer and GFCI (Exc: optional EPD for 460V.)
- Cable quick disconnect standard.
- Safety tested and listed with ETL & ETL-C, conforming to UL standards; and carries a 3rd party listing with CE.
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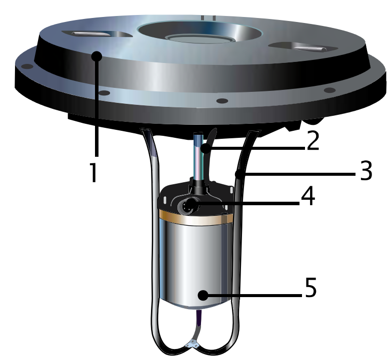


PRODUCT ILLUSTRATION

1. Rugged closed cell foam filled low visibility polyethylene float.
2. Precision pitched stainless steel impeller is virtually unbreakable.
3. Protective arms secure motor unit and allow for easy handling.
4. Electrical disconnect is part of upper plate to prevent accidental damage.
5. Enclosed in a corrosion resistant, durable 18 gauge/316 grade stainless steel motor housing, the oil-cooled, efficient 1725/1425 RPM custom built motor has dynamically balanced rotors to move high volumes of water.

Minimum operating depth is 40in or 1m with and without lights. See www.otterbine.com for product testing and package details.

60 HZ	1 HP	2 HP	3 HP	5 HP
Spray Height (ft)	1.5	2	3	4.5
Spray Diam. (ft)	4	7	9	11
GPM	920	1,525	2,100	3,000
Volt/Ph/Amp 1725@60hz	115/1/13.4 230/1/6.8	230/1/11.9	230/1/13.5 230/3/8.5 460/3/4.2	230/3/14.4 460/3/7.5

Product specifications and CADs can be found online through www.otterbine.com or www.caddetails.com

Water Works
With Otterbine

HIGH VOLUME
INDUSTRIAL AERATOR
Owner's Manual

A Guide to More Dependable
Water Quality Management
With Otterbine Barebo Inc.'s
1-5 Horsepower Surface Spray
Aerating Fountain

Welcome Aboard!
Welcome to the growing family of people who depend on aerating fountains for better water quality control and aesthetic improvement. Otterbine Barebo, Inc. moves its aerating fountain line into the next century with a revolutionary platform. This design offers an industry first five-year warranty with virtually no maintenance, reduced float visibility, and interchangeable spray patterns. All Otterbine products are safety tested and approved by ETL, ETL-C and CE

Water Quality Specialists
Barebo, Inc. is a team of scientists, engineers, and crafts persons who specialize in efforts to improve water quality. Otterbine aerating fountains are built at Barebo, Inc.'s 25,000 square foot factory in Emmaus, Pennsylvania. Each step in assembly is followed by a quality assurance check to maintain high quality.
The Concept 3 line of Otterbine aerators, made of stainless steel and high tech engineering plastics, reflects the results of aerator research and development programs that started in 1956, plus the experience gained through thousands of installations on commercial fish farms, golf courses, parks, and architectural applications.

Follow the Guidelines
You'll find guidelines for installing, operating, and maintaining your aerating fountain in the following pages. We strongly recommend that you read, understand, and apply these guidelines. They will help you get better performance and dependability from your Otterbine aerating fountain.


GEMINI


PHOENIX


TRI-STAR


COMET


SUNBURST


CONSTELLATION


ROCKET

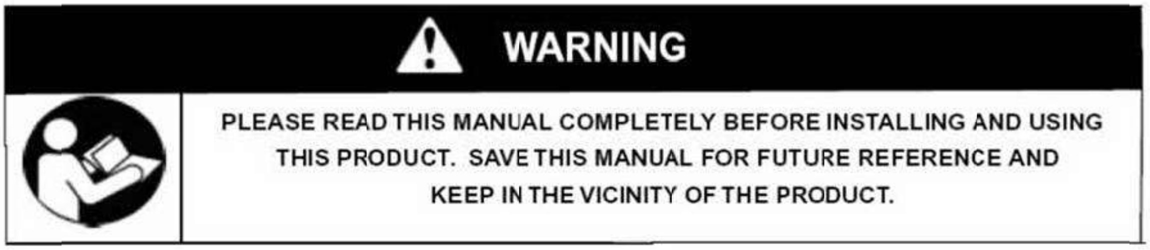

EQUINOX


GENESIS


SATURN

CONTENTS

SAFETY INSTRUCTIONS



ALL ELECTRICAL WORK MUST BE PERFORMED BY A QUALIFIED LICENSED ELECTRICIAN AND CONFORM WITH ALL APPLICABLE ELECTRICAL SAFETY CODES
Tous travaux électriques doivent être effectués par un électricien professionnel qualifié et conforme à tous les codes applicables sécurité électrique

ALWAYS SWITCH OFF/DISCONNECT ALL EQUIPMENT IN THE WATER BEFORE SERVICING OR PERFORMING ANY MAINTENANCE
Toujours éteindre l'équipement dans l'eau avant entretien ou de tout entretien

DO NOT OPERATE THE FOUNTAIN WHEN PEOPLE ARE IN THE WATER
Ne pas utiliser la fontaine quand les gens sont dans l’eau

CAUTION: KEEP HANDS CLEAR OF THE IMPELLER WHEN OPERATING!
ATTENTION: Garder les mains loin du turbine lors de l’utilisation!

WARNINGS

- Before entering, wading in or swimming in the water in which Otterbine Aerators or Fountains are installed, make sure they are PHYSICALLY disconnected from their electrical power sources.
- Aerators located in or near garden ponds and similar locations must be equipped with Ground Fault Circuit Interrupter.
- The permissible temperature range for this equipment is -12^{o} to 40^{o} C/10^{o} to 104^{o} F.
- It is possible for the water to become slightly polluted in the rare case that an oil leak occurs.
- If the power cord is damaged, it must be replaced by a special cord or assembly available from Otterbine/ Barebo, Inc. or an authorized Otterbine/Barebo, Inc. sales and service center.
- Avant d'entrer, pataugeant dans ou en nageant dans l'eau dans laquelle Aérateurs Otterbine ou fontaines sont installées, assurez-vous qu'ils sont physiquement déconnectés de leur source d'alimentation électrique.
- Aérateurs situés dans ou à proximité des bassins de jardin et des emplacements similaires doivent être équipés de disjoncteur.
- La plage de température admissible pour cet appareil est-12 o à 40 oC/10 o à 104 oF aux.
- Il est possible pour que l'eau devient légèrement polluées dans les rares cas où une fuite d'huile se produit.
- Si le cordon d'alimentation est endommagé, il doit être remplacé par un cordon spécial ou de montage disponible à partir Otterbine / Barebo, Inc ou une autorisation Otterbine / Barebo, les ventes Inc et centre de service.

INSPECT AERATOR EQUIPMENT

Immediately report any shipping damage to the carrier that delivered your aerator.

Inspect your aerator and verify the following:
Unit - Check the nameplate located on the housing of the aerator unit to make sure you have received the correct horsepower and voltage aerator.

Power Control Center - Verify the PCC is compatible with the aerator unit horsepower and voltage. Refer to the electrical specifications on the nameplate located inside on the door of the PCC.

Power Cable Assembly - Verify the correct cable gauge and length.

For proper warranty consideration return your Otterbine warranty registration card.

ELECTRICAL/PCC INSTALLATION

ELECTRICAL INSTALLATION MUST BE PERFORMED BY A QUALIFIED LICENSED ELECTRICIAN AND CONFORM TO ALL APPLICABLE LOCAL AND NATIONAL CODES

DISCONNECT EQUIPMENT FROM ELECTRICAL SUPPLY BEFORE SERVICING OR PERFORMING MAINTENANCE

Use Only OTTERBINE power cord. Do not splice or repair the cord, replacement is necessary if damage occurs.

The standard Power Control Center includes a fiberglass NEMA 4X enclosure with twenty-four hour timer control in the auto setting or manual control of the aerator unit, the required motor short circuit, ground fault and overcurrent protection, surge protection, and personnel GFCI protection (except 460V 60Hz. applications). On 460V units EPD (Equipment Protection Device) is an optional accessory to provide 5, 10 or 30 mA ground fault protection.

Caution: GFCI Protection is required. If GFCI protection is not used, serious or FATAL electrical shock may occur.
Attention: GFCI/RCD de protection est nécessaire. Graves ou mortelles choc électrique peut se produire s'il n'est pas utilisé.

A. Feeder

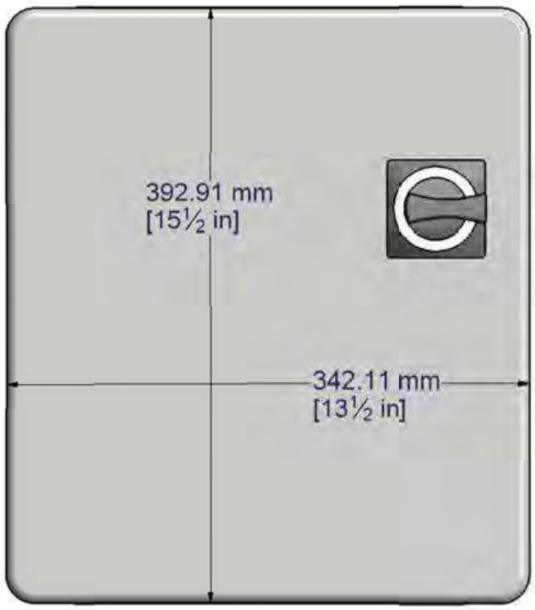
1. Proper feeder circuit protection in accordance with all applicable local and national codes **must** be provided to the power control center.
2. Be certain to properly size feeder conductors to allow for no more than 5% voltage drop for the entire circuit from the feeder source to the aerator unit. Failure to do so may damage the aerator and void product warranty.

60Hz. Electrical Specifications			
HP	Volts	Phase	Full Load Amps
1	115	1	15.0
1	208/230	1	6.8
2	208/230	1	11.5
3	208/230	1	12.9
3	208/230	3	8.2
3	380	3	4.7
3	460	3	4.3
5	208/230	3	14.8
5	380	3	7.8
5	460	3	7.4
5	575	3	6
50Hz. Electrical Specifications			
1	230	1	7.5
2	230	1	12.0
3	230	1	14.0
3	380/415	3	4.2
5	380/415	3	7

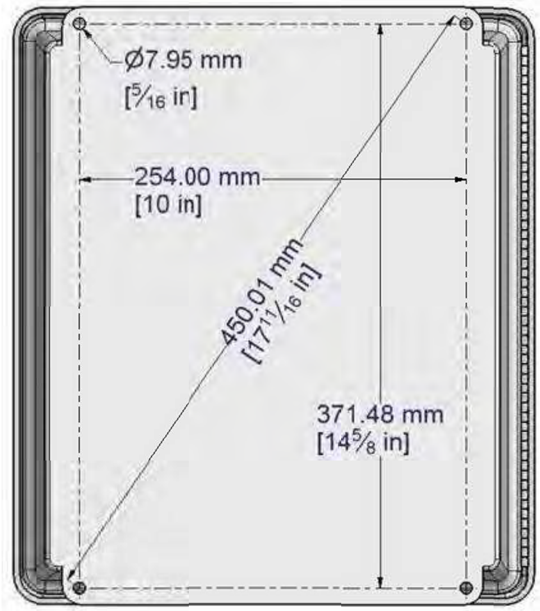
B. PCC Location

1. The power control center should be mounted where easily visible from the shoreline where the aerator is located.
Important: The power control center **shall not** be accessible from the water.
Important: Le Centre de Contrôle de la puissance ne doit pas être accessible à partir de l'eau

C. PCC Mounting
1. To prevent damage to the enclosure mount the enclosure using all four (4) mounting holes.
2. Whenever possible do not mount the PCC in direct sun light.

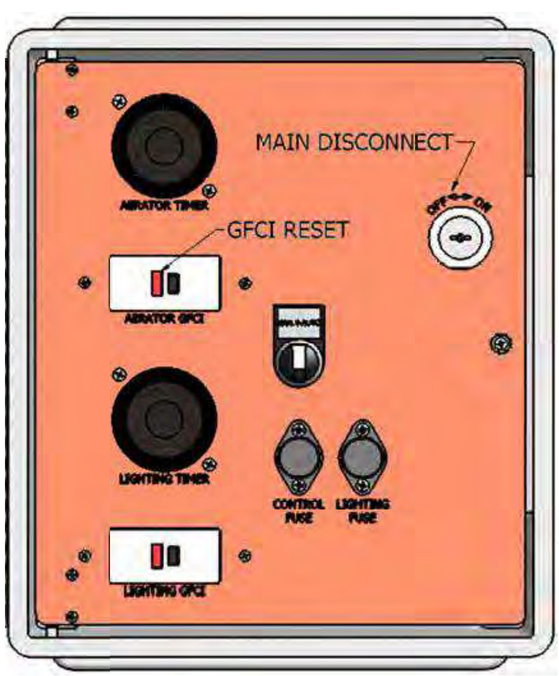


OVERALL DIMENSION

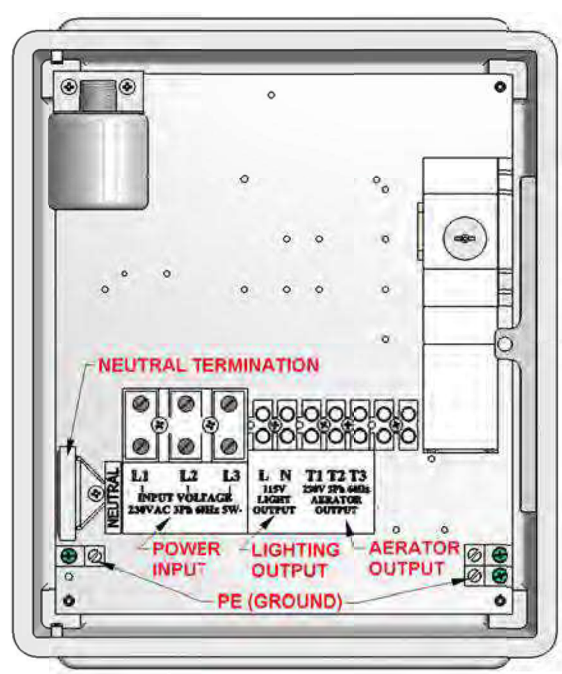


MOUNTING HOLE LAYOUT

D. PCC Cables & Connections
1. Only Otterbine Barebo, Inc. factory approved power cord is to be used from the PCC to the aeration unit with no junction boxes or splices. **Only** use power cord gauges and lengths specified by Otterbine at the time of cable purchase. (Contact your Otterbine Distributor for proper cable sizing)
2. It is recommended that all exposed cable between the PCC and the shoreline be installed in non-metallic conduit. It is **important** that aerator and lighting cables be installed in individual conduits to avoid induced interference between cables which causes random GFCI tripping.
3. **Always** use strain relief cord connectors to attach the Otterbine cable to the PCC.
4. Cables and conduits must only enter into the bottom of the PCC.
5. Factory connections may loosen during shipping. Verify tightness of all screw terminal connections before energizing.
6. Power input and output wiring connections are accessed from the bottom of the enclosure. The terminal blocks for the cable connections are located behind the hinged swing panel. Loosen the captive screw on the right center of the swing panel for access.
Terminal Torque Values: **Input** – 45 in/lb. Maximum, **Output** – 30 in/lb. Maximum



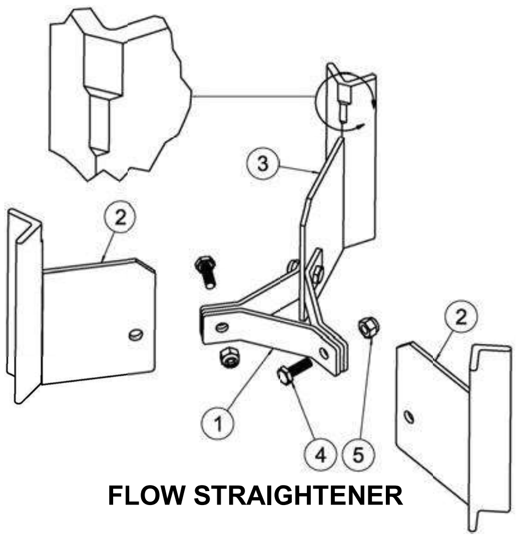
VIEW OF SWING PANEL



VIEW OF SUB-PANEL

HIGH VOLUME UNIT ASSEMBLY

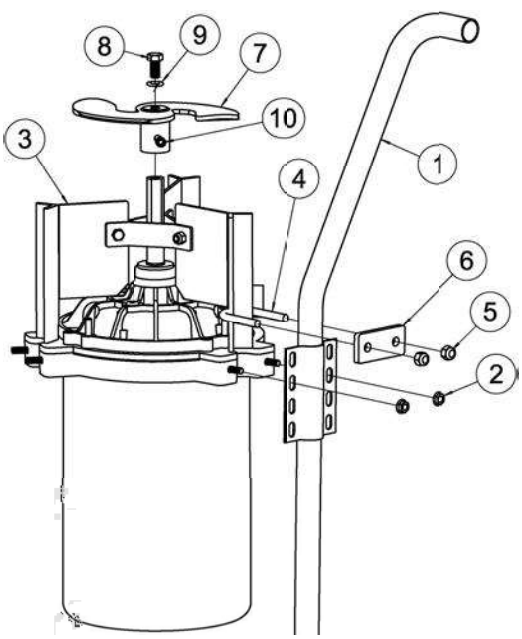
Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Flow Straightener Mounting Bracket	40-0112	3
2	Flow Straightener "A"	40-0113	2
3	Flow Straightener "B"	40-0114	1
4	1/4-20 x 3/4" S/S Hex Bolt	EP5103	3
5	1/4-20 S/S Locknut	C2-112	3



FLOW STRAIGHTENER

A. Assemble Flow Straightener (shown above)
1. Assemble the Flow Straightener Assembly on a flat surface as shown above. Tighten the hardware.

Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Adjustable Support Arm	C2-304	1
2	1/4"-20 S/S Flange Nut	26-0001	6
3	Flow Straightener Assembly		1
4	Flow Straightener S/S U-Bolt	20-0011	3
5	5/16-18 S/S Nylon Hex Nut	GP1208	9
6	Flow Straightener Plate	40-0111	3
7	1HP 60Hz High Volume Impeller 2HP 60Hz/1HP 50Hz High Volume Impeller 3HP 60Hz/2HP 50Hz High Volume Impeller 5HP 60Hz/3HP 50Hz High Volume Impeller 5HP 50Hz High Volume Impeller	50-0013-001 50-0013-002 50-0013-003 50-0013-005 50-0013-006	1
8	3/8-16 x 3/4" S/S Hex Bolt	C2-111	1
9	3/8 Split Washer Washer	EP6301	1
10	Impeller Set Screw	40-0002	1



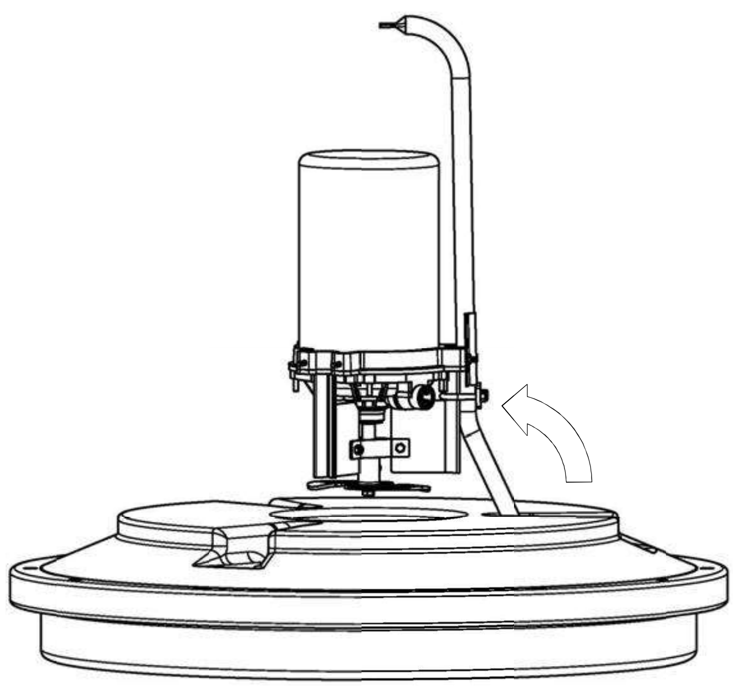
FLOW STRAIGHTENER, IMPELLER & ADJ. ARM

B. Install Adjustable Support Arm (below left)
1. Attach the adjustable support arm to the mounting ring using (2) 1/4" flange nuts. Torque to 10-12 ft.-lbs. Center the bolts in the second row of slots.

C. Install Flow Straightener
1. Center the flow straightener assembly on top of the power unit. Align the "B" Flow Straightener (3 shown above) with the stud on the motor base plate. Secure to the Support Arm with a U-Bolt, mounting Plate and locknuts (4, 5 & 6). Tighten the locknuts evenly.

D. Install Impeller
1. Place the impeller onto the motor shaft.
2. Align the set screw (10) to a flat on the shaft. Tighten the set screw using a hex key driver.
3. Install impeller bolt and split lock washer (8 & 9) Torque the bolt to 35 ft.-lbs.

E. Placing Power Unit in Float (shown below)
1. Place the float on a flat surface with the top side down.
2. Invert the power unit assembly and insert the top of the adjustable support arm through one of the pockets in the float. The support assembly should be standing upright in the float.



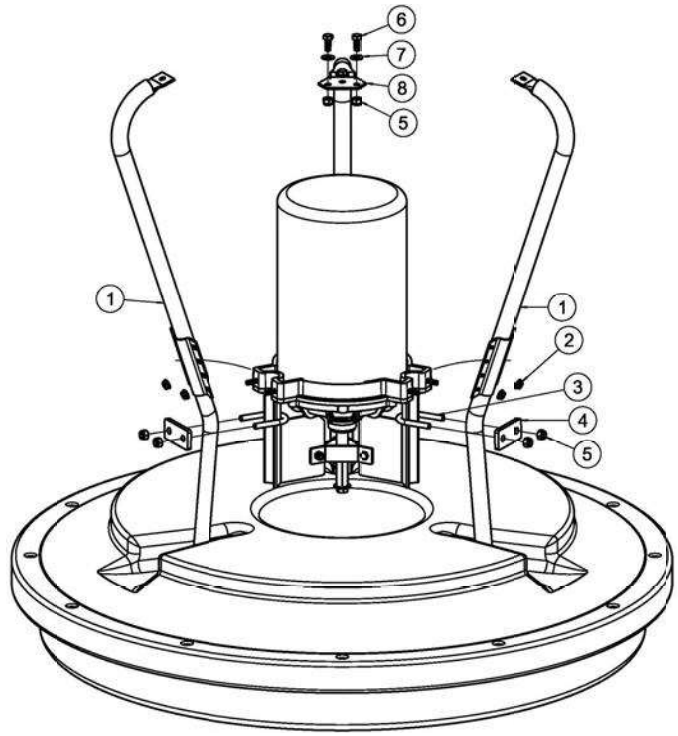
PLACE POWER UNIT IN FLOAT

F. Install Remaining Support Arms (shown on right)

1. Insert the top of the second and third support arms into the pockets of the float.
2. Attach each of these arms to the mounting ring with (2) 1/4" flange nuts. Use the second set of holes down from the top of the support arm. Torque to 10-12 ft-lbs.
3. Secure the Flow Straightener to the two Support Arms just installed with a U-Bolt, a mounting Plate and two nylon locknuts for each. Tighten the locknuts evenly.
4. Attach the bottom of the support arms to the support arm brace with (1) 5/16" locknut, (1) 5/16" flat washer, and (1) 5/16" hex bolt for each of the three arms. Torque the bolts to 15-17 ft.-lbs.

NOTE: When the support arms are assembled correctly, a triangle should form where they come together at the support arm brace.

Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	C2 Support Arm	C2-303	2
2	1/4"-20 S/S Flange Nut	26-0001	6
3	Flow Straightener S/S U-Bolt	20-0011	3
4	Flow Straightener Plate	40-0111	3
5	5/16-18 S/S Nylon Hex Nut	GP1208	9
6	5/16-18 x 3/4" S/S Hex Bolt	106-302	3
7	5/16" S/S Flat washer	28-0018	3
8	Support Arm Brace Plate	C2-301	1

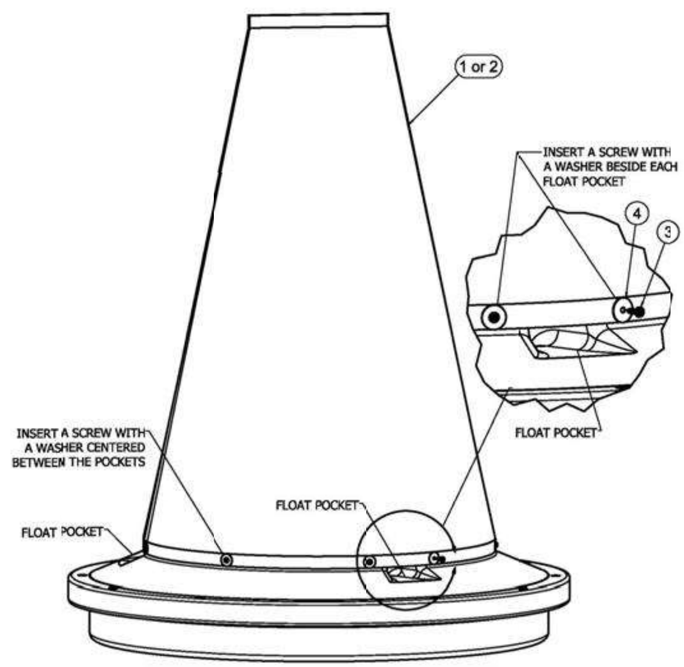


ATTACH REMAINING SUPPORT ARMS

G. Screen Installation

1. Pull screen over motor unit and support arms until it reaches the first ridge on the float (next page)
2. Route the cord/cords through the float pockets where the support arms fit into the float. Choose one pocket for all cables. Pull approximately two inches of the screen past the Mounting Ring to adequately cover the pockets.
3. Fasten the screen to the float with the washers and screws provided. Fasten a screw and washer on both sides of each float pocket. Screw the three remaining screws and washers through the screen into float between the each pocket.

Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
	1/4" Screen Kit	F-900-002F	
	1/2" Screen Kit	F-800-001B	
1	C2 1/4" Screen	15-0001	1
2	C2 1/2" Screen	15-0002	1
3	8-32 x 3/4" S/S Sheet Metal Screw	BP2803B	9
4	#10 x 1" Fender Washer	800-011	9



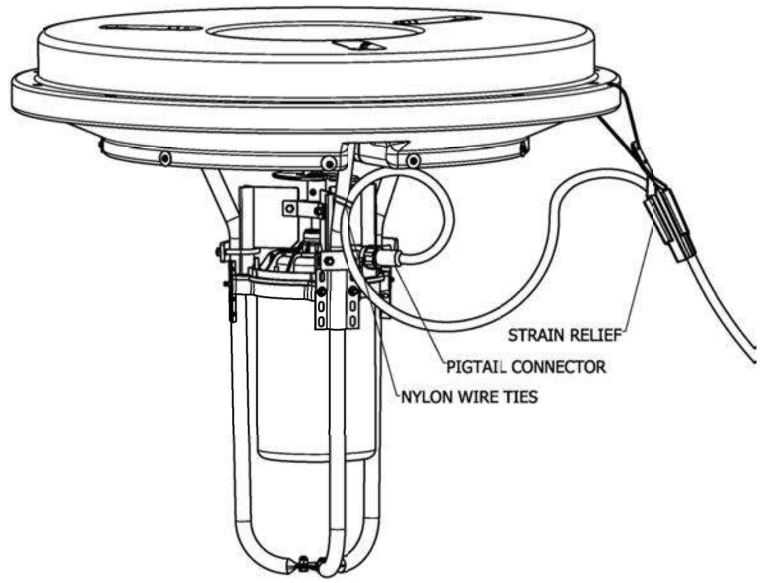
ATTACH SCREEN

PHYSICAL INSTALLATION

WARNING: DISCONNECT POWER BEFORE INSTALLING, REMOVING, OR SERVICING UNIT

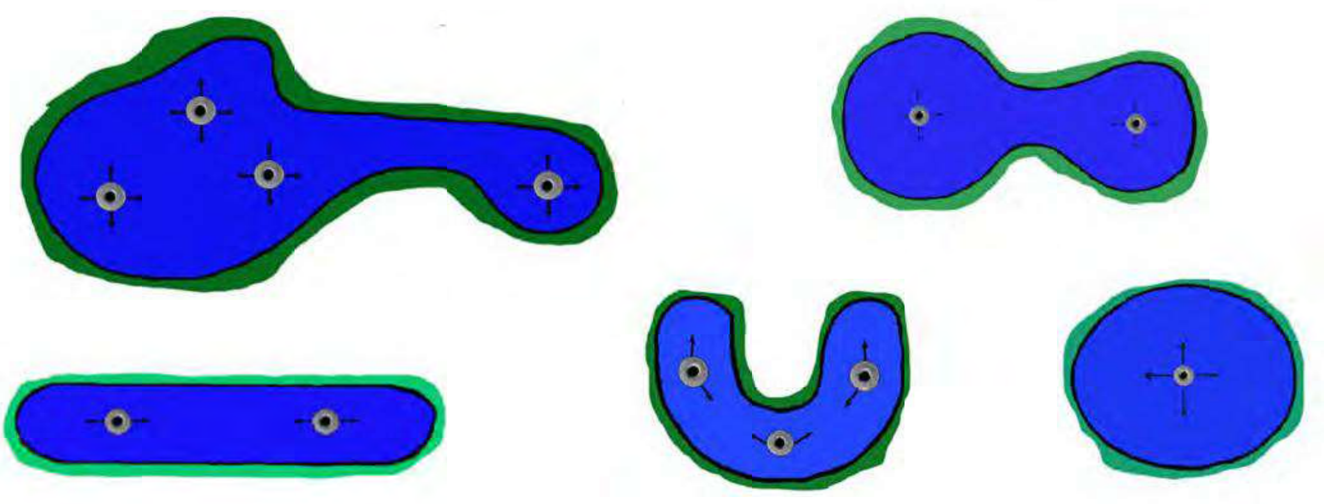
Concept 2 Otterbine aerators require **a minimum 40"/1m** of water depth. If the water is too shallow or fluctuations in water depth occur, it will be necessary to remove a portion of the pond bottom beneath the aerator.

A. Attach your Otterbine power cable to the aerator.
1. Align the pigtail connector on the cable up to the pin configuration on the bulkhead on the aerator. Thread the nut onto the bulkhead, hand tighten only, do not use tools on the pigtail connector nut. Do not over tighten. **Over tightening may cause the connector to fracture and possibly cause an electrical short circuit.**
2. All ratings use 4 pin connectors.
3. A small amount of silicon compound has been factory applied to the female end of the aerator connector. The compound and is necessary to make a waterproof seal between the two connectors.**DO NOT REMOVE COMPOUND!** When servicing the aerator make sure to re-apply compound. (Otterbine P/N: 48-0001).
4. **Install the cable strain relief device.** Pass the wire hoop from the strain relief through one of the holes in the float. Reattach wire hoop to strain relief.
5. For additional protection fasten the power cable to a support arm using the cable ties provided.



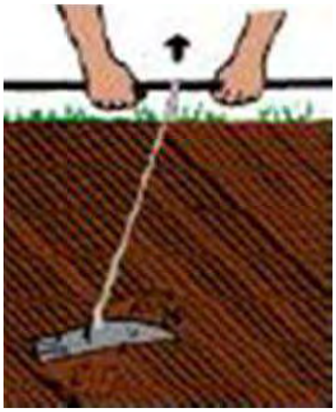
B. Pre-Startup Checks (To be performed by a qualified technician)
1. Factory connections may loosen during shipping. Verify tightness of all screw terminal connections before energizing.
2. Apply power to the PCC. Verify the voltage to the PCC at the input terminals is correct and matches the nameplate rating of the aerator.
For 115V & 230V Single Phase & 230V Three Phase Units: The voltage between L1 on the input terminal block to the neutral terminal must measure a nominal 120V.
3. Allowing the main door to be open and with the swing panel door closed turn on main disconnect. (See page 7)
4. Activate the GFCI/s located on the swing panel by pressing the "RESET" button.
5. With the aerator unit on the shore check for correct motor rotation. Briefly "bump" (turn on only long enough to establish operation and direction of rotation) the MOA (Manual-Off-Auto) switch to "MAN" (See Page 12) while observing the motor shaft rotation. **(IMPORTANT! Aerator Shaft rotation MUST BE CCW looking at the top/impeller end of the unit)**.

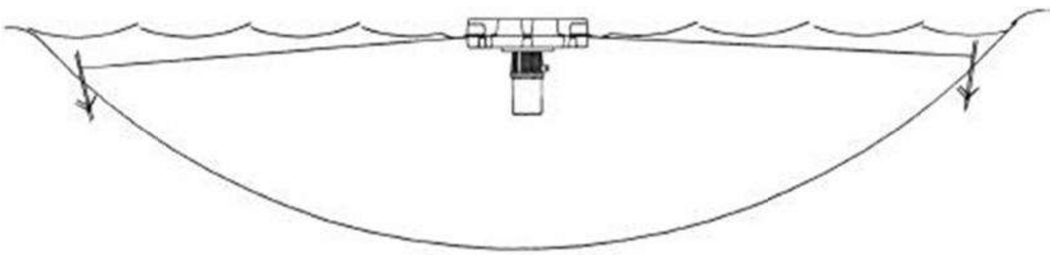
C. Launching the Aerator
1. It is important to choose the correct location for your Otterbine aerator. Placement affects how well your Otterbine aerator is able to keep your pond clean. The following diagrams represent the most common types of ponds and the most effective aerator placement.



2. Select the method of securing your aerator, mooring (see step C3) or anchoring (see step C4). Mooring provides for easier installation and servicing of the aerator.

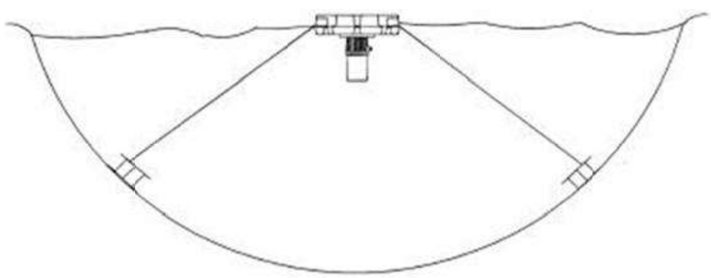
3. **Mooring:** The following items are required to moor your Otterbine aerator. Use only brass and stainless steel hardware. Otterbine recommends using 1/4"(0.63cm) or 1/2"(1.25cm) polypropylene rope or stainless steel cable for mooring lines. At the mooring points you will need a wooden stake, 1/2"(1.25cm) steel bar or a "duck bill" type earth anchor. The earth anchor allows the mooring lines to be hidden beneath the surface of the water. Install all anchoring points. Pound the first mooring point securely into the ground at the outer edge of the pond. If you are mooring with an earth anchor position the earth anchor two feet into the pond. The duckbill earth anchors are driven into the ground, using a drive rod and a heavy hammer, drive downward until they reach approximately two feet into the pond bottom. Remove the drive rod and pull up on cable. This planes or rotates the anchor into the load-lock position (see diagram on left). Fasten all of the mooring lines securely to the outer holes in the float. Launch the aerator into the water. Walk one mooring line around to the other side of the pond and pull your Otterbine aerator into the previously chosen location. Secure the aerator leaving enough slack in the lines to allow the aerator to turn 90 degrees or 1/4 turn. The slack in the lines will allow for proper start up, wave action and fluctuations in the water level. Proceed to step 5.





Mooring the Aerator

4. **Anchoring:** The following items are required to anchor your Otterbine aerator. Use only stainless steel and brass hardware. Otterbine recommends using 1/4"(0.63cm) or 1/2"(1.25cm) polypropylene rope or stainless steel cable for anchoring lines, two 60 - 80 lb. (27 - 36 kilo) weights for anchors and a small boat. Fasten all of the mooring lines securely to opposite outer holes in the float. Launch your aerator into the water upside down with the motor housing facing up. Place the anchors into the boat and tow the aerator into the predetermined location. Anchor location will vary depending on the depth of your pond (See chart). Drop the anchors with lines attached into the water at opposite locations. Secure the aerator leaving enough slack in the lines to allow the aerator to turn 90 degrees or 1/4 turn. The slack in the lines will allow for proper start up, wave action and fluctuations in the water level. Flip the unit over and proceed to step 5.



Anchoring the Aerator

MAXIMUM DEPTH		DISTANCE BETWEEN ANCHORS	
Feet	Meters	Feet	Meters
5	1.5	11	3.4
6	1.8	15	4.6
7	2.1	20	6.1
8	2.4	30	9.1
9	2.7	40	12.0
10	3.0	55	16.7
11	3.3	70	21.2
12	3.6	85	26.8
13	3.9	100	30.3
14	4.2	120	36.4
15	4.6	140	42.4

SYSTEM STARTUP

DO NOT ALLOW THE AERATOR TO OPERATE "DRY" OUT OF THE WATER

IMPORTANT: Otterbine aerators are designed to run in a Counterclockwise direction facing the top impeller end. Current unbalance for three phase systems shall not exceed 5%.
IMPORTANT: Aérateurs Otterbine sont conçus pour fonctionner dans le sens antihoraire regardant l'extrémité supérieure de la turbine. Courant de déséquilibre pour les trois systèmes de la phase ne doit pas dépasser 5%

A. User Control Functions
1. Main Disconnect Switch

MAIN DISCONNECT OFF
Removes Power to the Aerator for Maintenance/Servicing/Repair, Timers are not powered (Time of Day Needs to be Reset)

MAIN DISCONNECT ON
Power Applied, Mode of Operation Now Dependent on the Position of MOA Switch, Timers are Operating

MAIN DISCONNECT TRIPPED
Indicates a Fault Motor/Wiring Short Circuit Or Motor Current Overload

2. MANUAL-OFF-AUTO switch.

MOA IN OFF
Aerator & Lighting Will Not Function, Timers are Powered and Operating, GFCI's may be Reset

MOA IN AUTO
Allows Automatic Control of Aerator & Lighting by Timers & Other Control Options

MOA IN MANUAL
Turns on Aerator, Bypasses Timer & Non-Critical Control Functions

3. Timer operation.

a. Push **in** (towards center) all tripper pins on the timer dial. (As Shown)
b. Pull **out** only the tripper pins on the dial that are between the times you want the unit to run.

Example: If you want the unit on from 7:00AM - 5:00PM, pull out all of the tripper pins between those times. When the dial rotates to a tripper pin that is in, it will turn off.

c. Turn the outer dial clockwise to align the time of day to the stationary arrow positioned at "2 o'clock". Close the panel and turn the main disconnect on. When the main disconnect is off or in the case of power failure the timer/s will not operate and the time of day will need to be reset.
d. Set the "manual-off-auto" switch to the MANUAL or AUTO position. The MANUAL position on the switch will let your aerator run continuously. The AUTO position on the switch will allow the timer inside your aerator to operate the unit.

B. Energizing the Unit (To be performed by a qualified technician)
1. Single Phase Units: Correct motor rotation is factory determined and not field adjustable. Start the unit and record the operating voltage & amperage, power control center serial number and cable length and gauge on the label inside the power control panel.
2. Three Phase Units: Verify correct motor rotation (Counter Clockwise looking at the top/impeller end of the unit). Check current readings on each phase. Verify three phase operating currents are balanced within 5%. When correct, record the operating voltage & amperage, power control center serial number and cable length and gauge on the label inside the power control panel.
To calculate the percent of current unbalance:

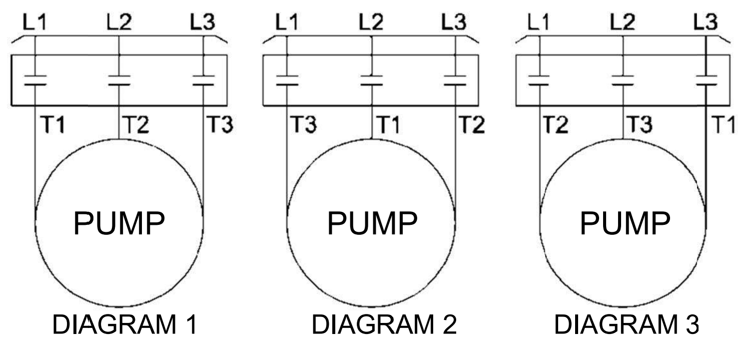
Determine the Average Current:

a. Measure each of the three phase currents
b. Add the three phase amperage values together.
c. Divide the sum by three.
d. This is the average current value.

Determine Current Unbalance:

a. Select the phase current with the greatest difference from the average (calculated above).
b. Determine the difference between this phase current and the average current value.
c. Divide the difference by the average.
d. Multiply the result by 100 to determine percent of unbalance.

3. Use connection diagram 1, 2 or 3 at right which results in the lowest current unbalance. Roll the motor cable leads on the aerator output terminal block in the same direction to avoid motor reversal. If the current unbalance is not corrected by rolling leads, locate the source of the unbalance and correct it.
a. When the phase farthest from the average stays on the same power lead after being moved the primary cause of unbalance is the power source.
b. When the phase farthest from the average moves on each of the hookups with a particular motor lead, then the primary cause of unbalance is the "motor side" of the circuit. Consider: damaged cable, leaking splice, poor connection, or a faulty motor as possible causes.



MAINTENANCE

Your Otterbine aerator requires periodic maintenance:

A. Once a year, disconnect the unit from the power source and physically inspect the aerator and underwater cable for any cuts, cracks or breaks. These may cause oil leaks and/or electrical shorts. Inspect and clean the pumping chamber components and screen.

B. After every three running seasons, a simple oil change is necessary to keep your unit running smoothly. Otterbine oil must be used for this oil change. Please contact your local Otterbine distributor to order a maintenance kit, P/N: C2-MKIT.
WARNING: Use the oil level gauge. Do not overfill motor housing with oil, may cause damage.

When a unit is properly cared for, it will give you years of trouble free service. If a problem does arise, please contact your Otterbine distributor or the factory directly at 1-800-AER8TER.

WINTERIZATION

If you live in a region of the country that experiences long periods of cold weather you may want to take your aerator out of the water. If an aerator becomes frozen-in, there is a possibility of motor damage.

Damage caused to the motor due to freezing will not be covered under warranty.

The **High Volume** pumps higher volumes of water and the spray pattern will not freeze easily. The unit will freeze in if the weather stays severe for a long enough period of time. You can decrease the chance of freezing in if you run these units 24 hours a day during long periods of extremely cold weather.

Maximum Cable Lengths (From Service Entrance to C2 Unit)

Concept 2 Maximum Cable Lengths											
	HP	Electrical Rating	Running Amps	12AWG / 4mm²		10AWG / 6mm²		8AWG / 10mm²		6AWG / 16mm²	
				Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
60Hz.	1	115V 1Ph 60Hz	13.4			150	45.72	250	76.2		
	1	208/230V 1Ph 60Hz	6.8	375 / 425	114 / 130	600 / 675	183 / 206	950 / 1000	290 / 305		
	2	208/230V 1Ph 60Hz	12.3	200 / 225	61 / 68.6	325 / 375	99.1 / 114	525 / 600	160 / 183	825 / 925	251 / 282
	3	208/230V 1Ph 60Hz	14.3			275 / 325	83.8 / 99.1	450 / 500	137 / 152	725 / 800	221 / 244
	3	208/230V 3Ph 60Hz	8.5	350 / 375	107 / 114	550 / 625	168 / 191	900 / 1000	274 / 305		
	3*	380V 3Ph 60Hz	4.7	1000	304.8						
	3*	460V 3Ph 60Hz	4.3	1000	304.8						
	5	208/230V 3Ph 60Hz	14.8	200 / 225	61 / 68.6	325 / 350	99.1 / 107	500 / 575	152 / 175		
	5*	380V 3Ph 60Hz	7.8	700	213.36	1000	304.8				
	5*	460V 3Ph 60Hz	7.4	900	274.32	1000	304.8				
	5*	575V 3Ph 60Hz	6	1000	304.8						
50Hz.	1	220-240V 1Ph 50Hz	8	350	106.68	550	167.64	875	266.7		
	2	220-240V 1Ph 50Hz	12	225	68.58	350	106.68	575	175.26		
	3	220-240V 1Ph 50Hz	14			300	91.44	500	152.4		
	3*	380/415V 3Ph 50Hz	4.2	1000 / 1000	305 / 305						
	5*	380/415V 3Ph 50Hz	7	775 / 850	236 / 259	1000 / 1000	305 / 305				

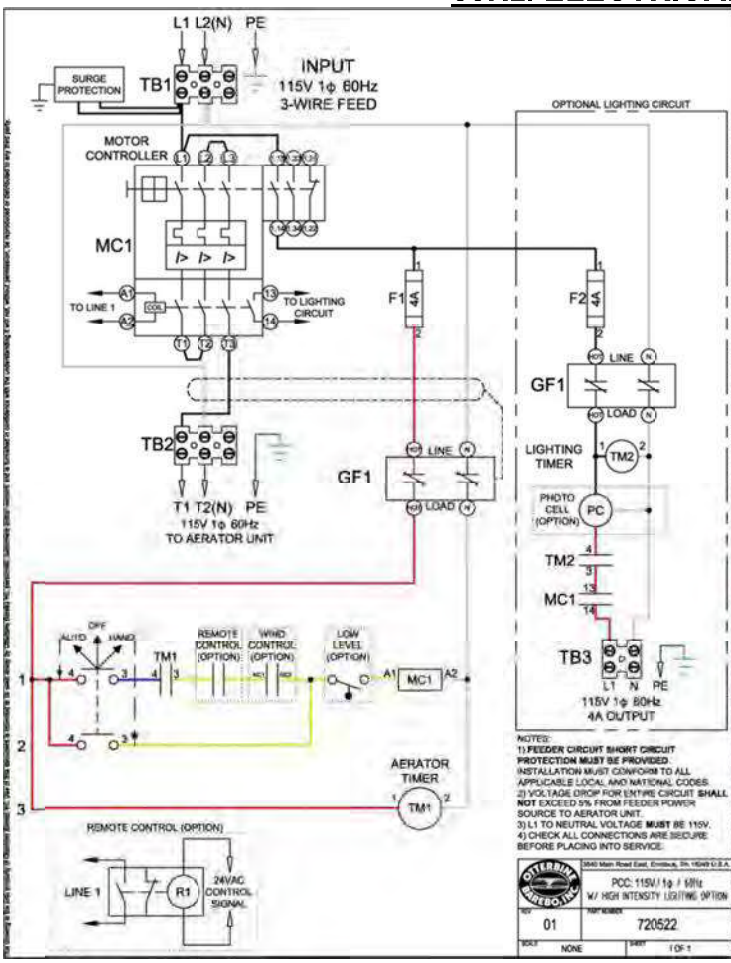
!IMPORTANT! Cable lengths are based on a 5% cable voltage drop between the PCC and the motor unit. It is important to consider the total voltage drop is 5% **including** the branch circuit to the PCC.

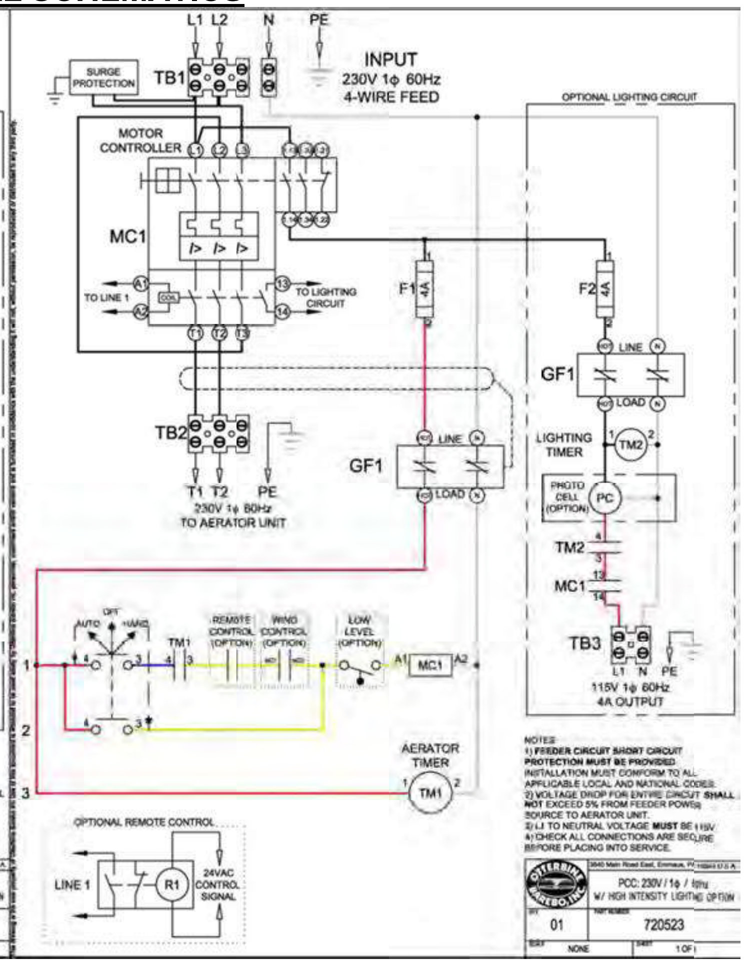
(*Cable for these systems may be available in longer lengths, call the factory to inquire)

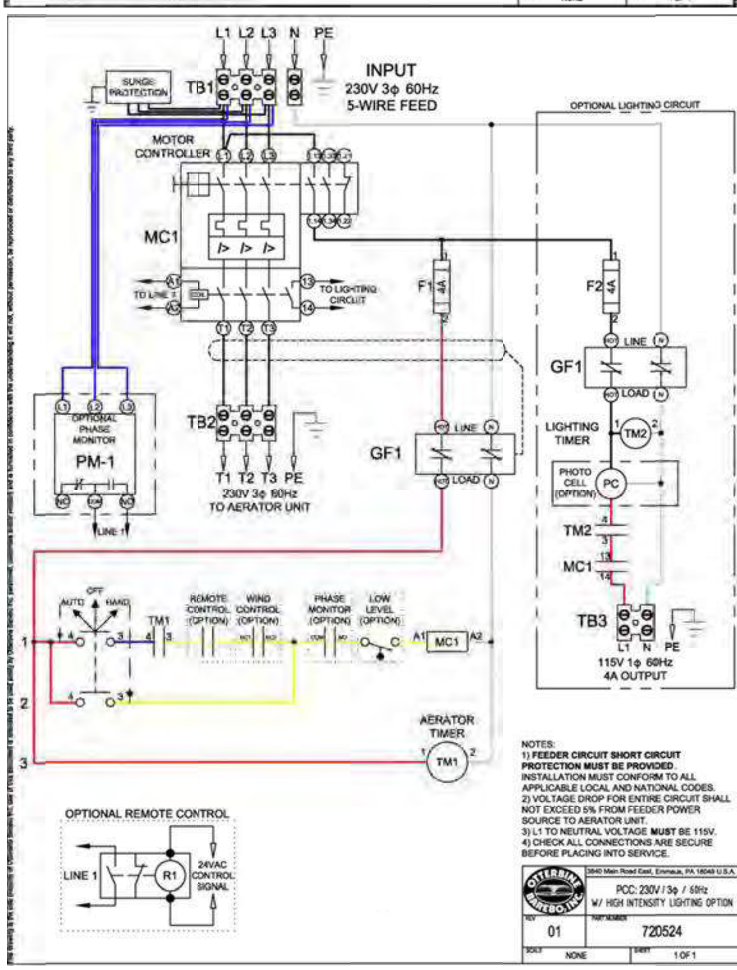
TROUBLESHOOTING GUIDE

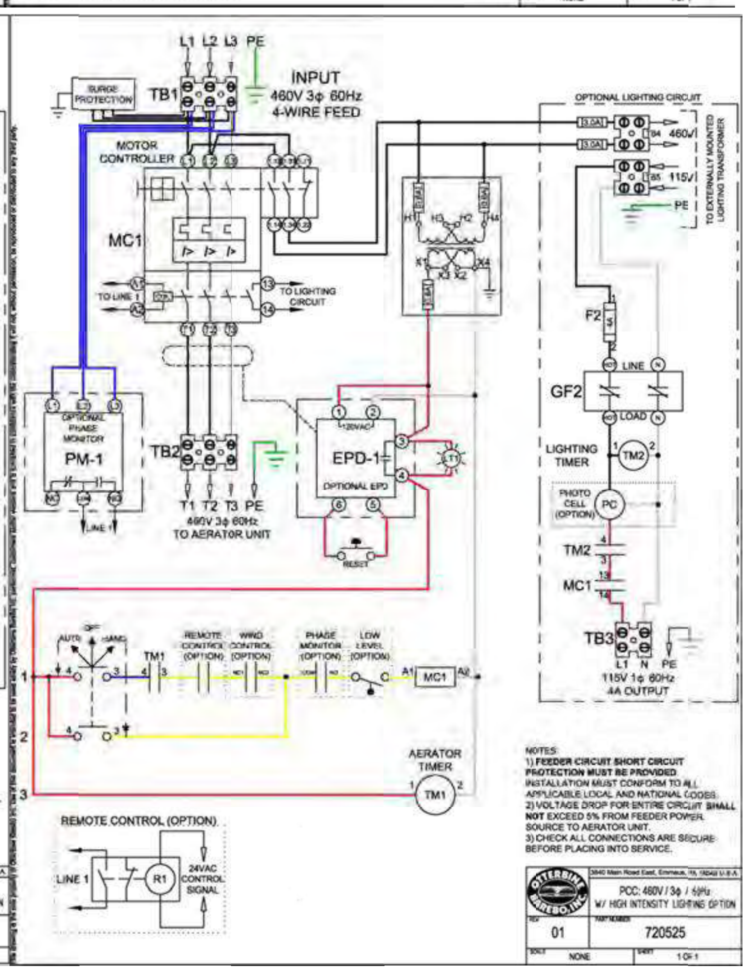
Small spray pattern (Spray drops **gradually**, i.e. minutes or hours).	Clogged intake	Remove debris
	Clogged screen	Remove debris
	Loose impeller	Tighten impeller bolt
Cavitation or low spray pattern. (Spray drops **suddenly,** less than one second.)	Low line voltage	Check voltage at the PCC & at the aerator. Make sure the unit is within the specified voltage range.
	Check for air bubbles surfacing around float	Make sure mooring and anchoring lines are securely tightened
	Debris between slinger and Impeller	Remove debris
Motor will not start	Breaker/fuse has tripped	Check circuit breaker or fuse, reset and/or replace, if necessary. Check voltage.
	Loose or broken terminals	Look for loose or broken terminals.
	Low voltage	Measure power to starter. Check acceptable maximum cable length (see below)
	Defective power cable	Check cable. If defective, call distributor.
	GFCI has Tripped	Reset and test GFCI device. If device trips again call electrician or distributor

60Hz. ELECTRICAL SCHEMATICS

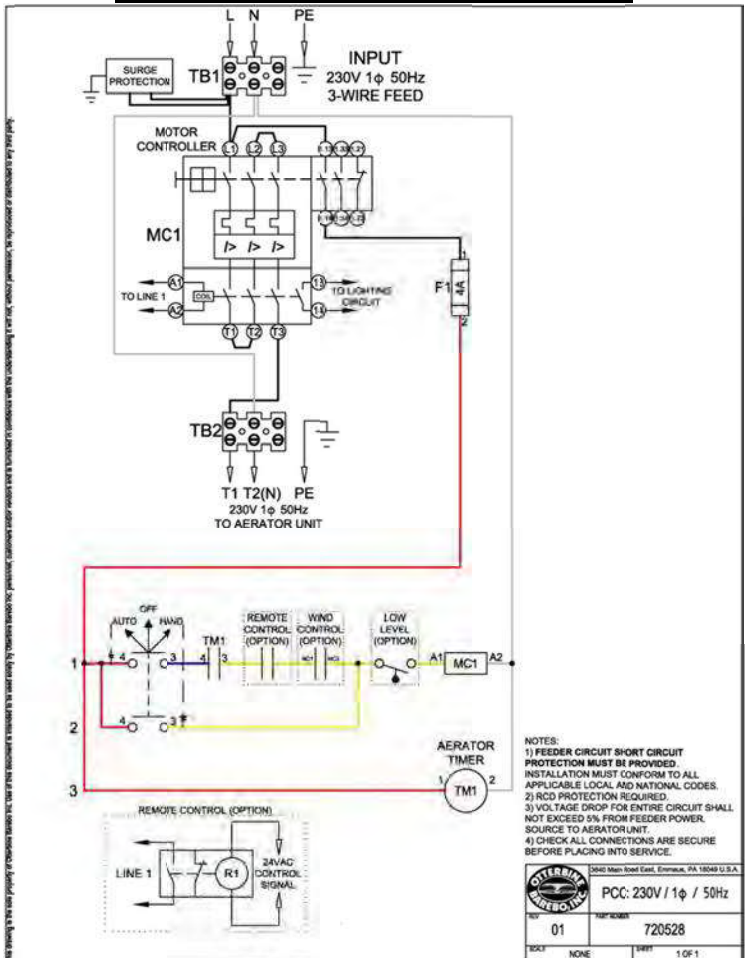


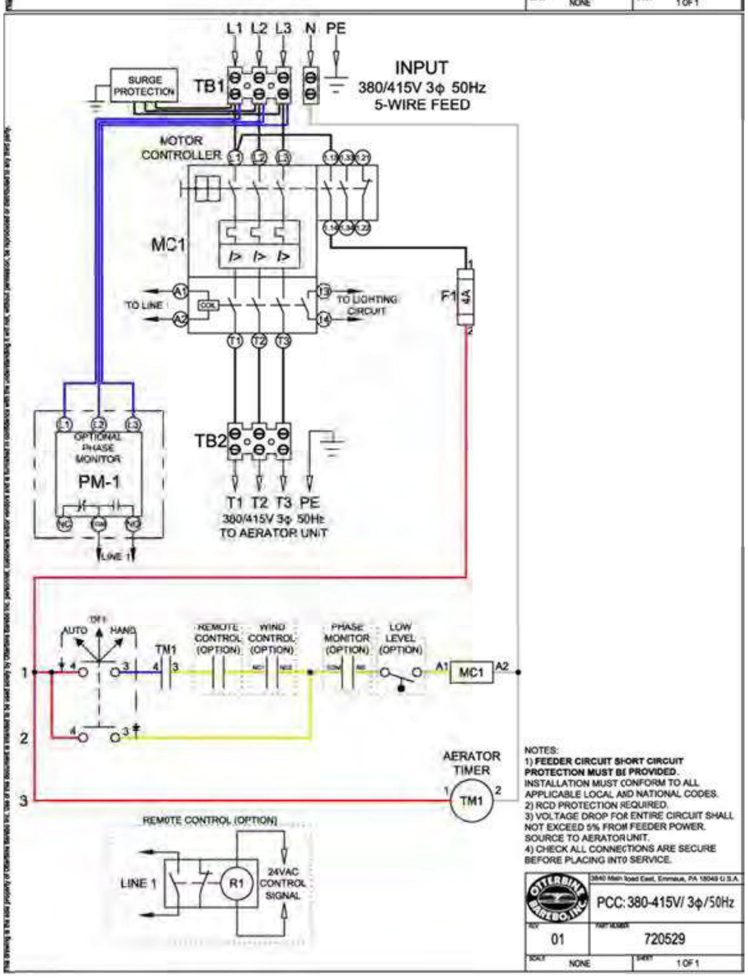






50Hz. ELECTRICAL SCHEMATICS





High Volume Industrial Aerator Domestic Technical Data

HP	Electrical Rating	Motor RPM	Running Amps	Spray Height (feet)	Spray Width (Feet)
1	115V 1Ph 60Hz	1725	13.4	2	5
1	208-230V 1Ph 60Hz	1725	6.8	2	5
2	208-230V 1Ph 60Hz	1725	11.5	2	7
3	208-230V 1Ph 60Hz	1725	12.9	3	9
3	208-230V 3Ph 60Hz	1725	8.2	3	9
3	460V 3Ph 60Hz	1725	4.1	3	9
5	208-230V 3Ph 60Hz	1725	14.4	4	11
5	460V 3Ph 60Hz	1725	7.5	4	11
5	575V 3Ph 60Hz	1725	6.0	4	11

High Volume Industrial Aerator International Technical Data

HP	Electrical Rating	Motor RPM	Runnin-g Amps	Spray Height (meters)	Spray Width (meters)
1	220V 1Ph 50Hz	1425	7.5	0.6	1.4
2	220V 1Ph 50Hz	1425	12	0.6	2
3	220V 1Ph 50Hz	1425	13.3	0.8	2.6
3	380/415V 3Ph 50Hz	1425	4.2	0.8	2.6
3	380V 3Ph 60Hz	1680	4.7	0.8	2.6
5	380/415V 3Ph 50Hz	1425	7.2	1.1	3.5
5	380V 3Ph 60Hz	1680	7.6	1.1	3.5

HP - Horsepower
V - Voltage
Ph. - Phase
Hz - Hertz
RPM - Revolutions per Minute

Limited 3 year (moving and related parts)
+ 5 year (non-moving parts) Warranty
Otterbine® Product

WARRANTY: Barebo, Inc 3840 Main Road East, Emmaus Pennsylvania 18049,U.S.A. hereby warrants, subject to the conditions hereinbelow set forth, that should the **OTTERBINE** product prove defective by reason of improper workmanship or materials at any time during the warranty period the Purchaser at retail will be guarantee that **BAREBO** will repair or replace the said **OTTERBINE** product as may be necessary to restore it to satisfactory operating condition, without any charge for materials or labor necessarily incident to such repair or replacement, provided that:

a) The enclosed Warranty Registration Card should be mailed to **BAREBO** within fifteen (15) days of the original receipt by the Purchaser at retail in order to avoid delays:

b) The **OTTERBINE** product must be delivered or shipped, prepaid, in its original container or a container offering an equal degree of protection, to **BAREBO** or a facility authorized by **BAREBO** to render the said repair or replacement services or, if purchased from an authorized **OTTERBINE** dealer, to such dealer;

c) The **OTTERBINE** product must not have been altered, repaired or serviced by anyone other than **BAREBO,** a service facility authorized by **BAREBO** to render such service, or by an authorized **BAREBO** dealer, and the serial number of the **OTTERBINE** product must not have been removed or altered: and

d) The **OTTERBINE** product must not have been subjected to lightning strikes and other Acts of God, vandalism, freezing-in, accident, misuse or abuse, and must have been installed in conformance with applicable electrical codes (including proper electrical protection), and also installed, operated and maintained in accordance with guidelines in the Owner's Manual shipped with the Otterbine product.

No implied warranties of any kind are made by **BAREBO** in connection with this **OTTERBINE** product, and no other warranties, whether expressed or implied, including implied warranties of merchantability and fitness for a particular purpose, shall apply to this **OTTERBINE** product. Should this **OTTERBINE** product prove defective in workmanship or material, the retail Purchaser's sole remedy shall be repair or replacement as is hereinabove expressly provided and, under no circumstances, shall **BAREBO** be liable for any loss, damage or injury, direct or consequential, arising out of the use of, or inability to use, the **OTTERBINE** product, including but not limited to retail Purchaser's cost, loss of profits, goodwill, damages due to loss of product or interruption of service, or personal injuries to Purchaser or any person.

MODEL (circle one): High Volume Industrial Aerator

HORSEPOWER (circle one): 1 2 3 5

VOLTAGE (circle one): 115 208-230 380 415 460 575

PHASE (circle one): Single Three HERTZ (circle one): 50 60

CORD GAUGE & LENGTH____

UNIT SERIAL NUMBER ____

PANEL SERIAL NUMBER ____

OPTIONS____

Water Works With Otterbine!

Otterbine/Barebo, Inc.
3840 Main Rd. East
Emmaus, PA. 18049
U.S.A.
1-800-AER8TER • (610) 965-6018
FAX: (610) 965-6050
e-mail: aeration@otterbine.com
www.otterbine.com

Appendix C - Aerating Fountain Literature

www.otterbine.com/gemini

GEMINI

AERATING FOUNTAIN

» Most energy efficient system in the industry.

» 5 year all-inclusive warranty.

» Operates in 30in or 75cm of water. (No additional depth needed when adding LED lights; additional 10in or 26cm required if adding high voltage lights.)

» Complete package includes assembled unit, power control center, and cable. (No PCC for 50HZ.)

» Power control center comes standard with surge arrestor, timer and GFCI (Exc: optional EPD for 460V.)

» Cable quick disconnect standard.

» Safety tested and listed with ETL & ETL-C, conforming to UL standards; and carries a 3rd party listing with CE.

» Effectively controls algae, aquatic weeds, and foul odors; while deterring insects and insect breeding.

» Published results from 3rd party testing verify highest oxygen transfer and pumping rates in the industry.

Product specifications and CADs can be found online through www.otterbine.com or www.caddetails.com.

We Guarantee that You'll Love Your Pattern

PRODUCT ILLUSTRATION

1. High-tech thermal plastic pumping chambers are staged to allow for easy interchange.
2. Rugged low visibility closed cell foam filled float includes handles and protective pockets for lights when applicable.
3. Industrial strength thermal plastic screen helps keep debris out of the unit.
4. Electrical quick disconnect is part of the upper plate to prevent damage.
5. Mixed flow pumping system achieves maximum pumping capacities.
6. Oil cooled, efficient 3450/2875 RPM custom built motor incorporates a g-type seal to ensure dependability and long life.
7. Corrosion resistant, durable 18 gauge/316 grade stainless steel motor housing.

60 HZ	1 HP	2 HP	3 HP	5 HP
Spray Height (ft)	5	9	12	15
Spray Diam. (ft)	10	16	24	34
GPM	555	665	800	1,125
Volt/Ph/Amp 3450@60hz	115/1/15 230/1/7.5	230/1/12.4	230/1/14 230/3/8.6 460/3/4.3	230/1/23 230/3/13.4 460/3/7.2

Manufactured by: Otterbine® Barebo, Inc. | 3840 Main Road East | Emmaus, PA 18049 U.S.A | PH: 610-965-6018

Water Works With Otterbine

CONCEPT$_3$

Owner's Manual

A Guide to More Dependable
Water Quality Management
With Otterbine Barebo Inc.'s
1, 2, 3 & 5 Horsepower Surface Spray
Aerating Fountain

Welcome Aboard!
Welcome to the growing family of people who depend on aerating fountains for better water quality control and aesthetic improvement. Otterbine Barebo, Inc. moves its aerating fountain line into the next century with a revolutionary platform. This design offers an industry first five-year warranty with virtually no maintenance, reduced float visibility, and interchangeable spray patterns. All Otterbine products are safety tested and approved by ETL, ETL-C and CE

CONTENTS

Water Quality Specialists
Barebo, Inc. is a team of scientists, engineers, and crafts persons who specialize in efforts to improve water quality. Otterbine aerating fountains are built at Barebo, Inc.'s 25,000 square foot factory in Emmaus, Pennsylvania.
The Concept 3 line of Otterbine aerators, made of stainless steel and high tech engineering plastics, reflects the results of aerator research and development programs that started in 1956, plus the experience gained through thousands of installations on commercial fish farms, golf courses, parks, and architectural applications.

75-0073 Revision 08 Concept 3 Owner's Manual

SAFETY INSTRUCTIONS

⚠ WARNING

PLEASE READ THIS MANUAL COMPLETELY BEFORE INSTALLING AND USING THIS PRODUCT. SAVE THIS MANUAL FOR FUTURE REFERENCE AND KEEP IN THE VICINITY OF THE PRODUCT.

ALL ELECTRICAL WORK MUST BE PERFORMED BY A QUALIFIED LICENSED ELECTRICIAN AND CONFORM WITH ALL APPLICABLE ELECTRICAL SAFETY CODES
Tous travaux électriques doivent être effectués par un électricien professionnel qualifié et conforme à tous les codes applicables sécurité électrique

ALWAYS SWITCH OFF/DISCONNECT ALL EQUIPMENT IN THE WATER BEFORE SERVICING OR PERFORMING ANY MAINTENANCE
Toujours éteindre l'équipement dans l'eau avant entretien ou de tout entretien

DO NOT OPERATE THE FOUNTAIN WHEN PEOPLE ARE IN THE WATER
Ne pas utiliser la fontaine quand les gens sont dans l'eau

CAUTION: KEEP HANDS CLEAR OF THE IMPELLER WHEN OPERATING!
ATTENTION: Garder les mains loin du turbine lors de l'utilisation!

WARNINGS

- Before entering, wading in or swimming in the water in which Otterbine Aerators or Fountains are installed, make sure they are PHYSICALLY disconnected from their electrical power sources.
- Aerators located in or near garden ponds and similar locations must be equipped with Ground Fault Circuit Interrupter.
- The permissible temperature range for this equipment is -12° to 40° C/10° to 104° F.
- It is possible for the water to become slightly polluted in the rare case that an oil leak occurs.
- If the power cord is damaged, it must be replaced by a special cord or assembly available from Otterbine/ Barebo, Inc. or an authorized Otterbine/Barebo, Inc. sales and service center.
- Avant d'entrer, pataugeant dans ou en nageant dans l'eau dans laquelle Aérateurs Otterbine ou fontaines sont installées, assurez-vous qu'ils sont physiquement déconnectés de leur source d'alimentation électrique.
- Aérateurs situés dans ou à proximité des bassins de jardin et des emplacements similaires doivent être équipés de disjoncteur.
- La plage de température admissible pour cet appareil est-12 o à 40 oC/10 o à 104 oF aux.
- Il est possible pour que l'eau devient légèrement polluées dans les rares cas où une fuite d'huile se produit.
- Si le cordon d'alimentation est endommagé, il doit être remplacé par un cordon spécial ou de montage disponible à partir Otterbine / Barebo, Inc ou une autorisation Otterbine / Barebo, les ventes Inc et centre de service.

INSPECT AERATOR EQUIPMENT

Immediately report any shipping damage to the carrier that delivered your aerator.

Inspect your aerator and verify the following:
Unit - Check the nameplate located on the housing of the aerator unit to make sure you have received the correct horsepower and voltage aerator.

Power Control Center - Verify the PCC is compatible with the aerator unit horsepower and voltage. Refer to the electrical specifications on the nameplate located inside on the door of the PCC.

Power Cable Assembly - Verify the correct cable gauge and length.

For proper warranty consideration return your Otterbine warranty registration card.

ELECTRICAL/PCC INSTALLATION

ELECTRICAL INSTALLATION MUST BE PERFORMED BY A QUALIFIED LICENSED ELECTRICIAN AND CONFORM TO ALL APPLICABLE LOCAL AND NATIONAL CODES

DISCONNECT EQUIPMENT FROM ELECTRICAL SUPPLY BEFORE SERVICING OR PERFORMING MAINTENANCE

Use Only OTTERBINE power cord. Do not splice or repair the cord, replacement is necessary if damage occurs.

The standard Power Control Center includes a fiberglass NEMA 4X enclosure with twenty-four hour timer control in the auto setting or manual control of the aerator unit, the required motor short circuit, ground fault and overcurrent protection, surge protection, and personnel GFCI protection (except 460V 60Hz. applications). On 460V units EPD (Equipment Protection Device) is an optional accessory to provide 5, 10 or 30 mA ground fault protection.

Caution: GFCI Protection is required. If GFCI protection is not used, serious or FATAL electrical shock may occur.
Attention: GFCI/RCD de protection est nécessaire. Graves ou mortelles choc électrique peut se produire s'il n'est pas utilisé.

A. Feeder

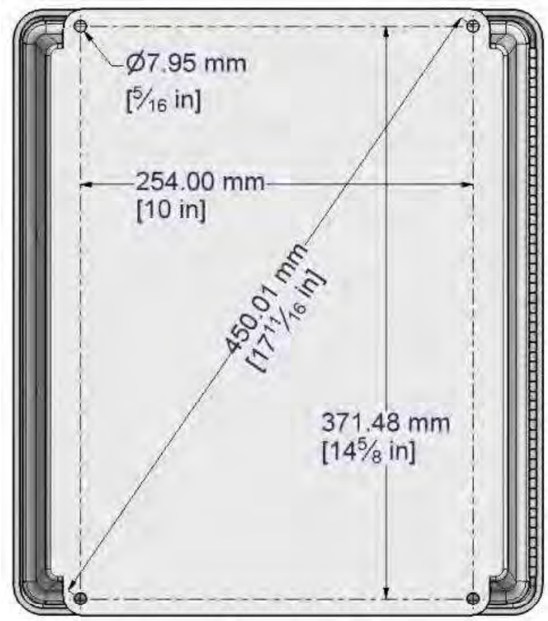
1. Proper feeder circuit protection in accordance with all applicable local and national codes **must** be provided to the power control center.
2. Be certain to properly size feeder conductors to allow for no more than 5% voltage drop for the entire circuit from the feeder source to the aerator unit. Failure to do so may damage the aerator and void product warranty.

60Hz. Electrical Specifications			
HP	**Volts**	**Phase**	**Full Load Amps**
1	115	1	15.5
1	208/230	1	8.3/7.5
2	208/230	1	13.7/12.4
3	208/230	1	15.5/14
3	208/230	3	9.7/8.6
3	380	3	4.6
3	460	3	4.3
5	230 Only	1	23
5	208/230	3	15.1/13.4
5	380	3	7.6
5	460	3	7.2
5	575	3	5.5

B. PCC Location

1. The power control center should be mounted where easily visible from the shoreline where the aerator is located.
Important: The power control center **shall not** be accessible from the water.
Important: Le Centre de Contrôle de la puissance ne doit pas être accessible à partir de l'eau

OVERALL DIMENSION

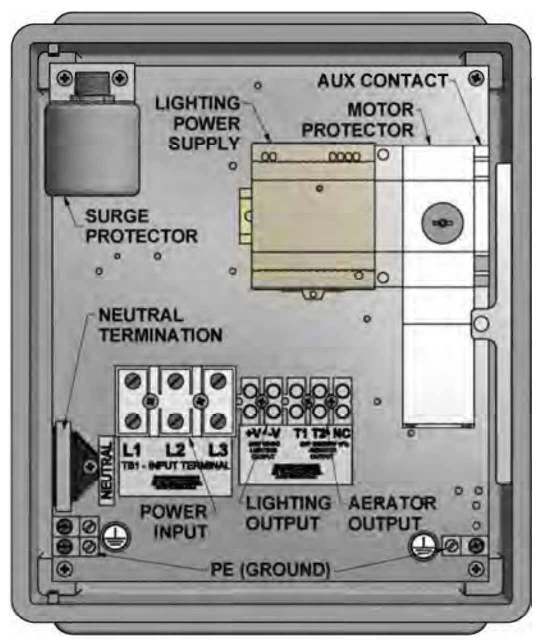


MOUNTING HOLE LAYOUT

C. PCC Mounting
1. To prevent damage to the enclosure mount the enclosure using all four (4) mounting holes.
2. Whenever possible do not mount the PCC in direct sun light.

D. PCC Cables & Connections
1. Only Otterbine Barebo, Inc. factory approved power cord is to be used from the PCC to the aeration unit with no junction boxes or splices. **Only** use power cord gauges and lengths specified by Otterbine at the time of cable purchase. (Contact your Otterbine Distributor for proper cable sizing)
2. It is recommended that all exposed cable between the PCC and the shoreline be installed in non-metallic conduit. It is **important** that aerator and lighting cables be installed in individual conduits to avoid induced interference between cables which causes random GFCI tripping.
3. **Always** use strain relief cord connectors to attach the Otterbine cable to the PCC.
4. Cables and conduits must only enter into the bottom of the PCC.
5. Factory connections may loosen during shipping. Verify tightness of all screw terminal connections before energizing.
6. Power input and output wiring connections are accessed from the bottom of the enclosure. The terminal blocks for the cable connections are located behind the hinged swing panel. Loosen the captive screw on the right center of the swing panel for access.
Terminal Torque Values: **Input –** 45 in/lb. Maximum, **Output –** 30 in/lb. Maximum

SWING PANEL VIEW



SUB-PANEL VIEW

UNIT ASSEMBLY

READ THE INSTRUCTIONS: Improper assembly may result in damage to the unit.

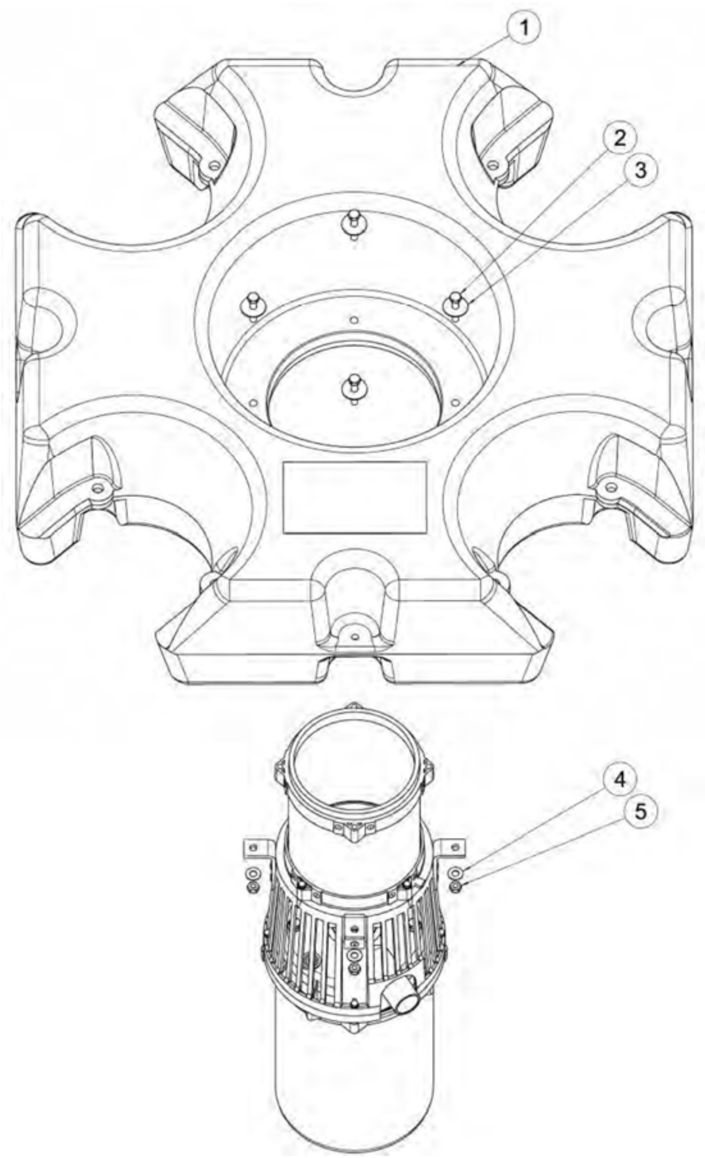
NOTES:
***Genesis Pump Chamber; The Float MUST be mounted before the Genesis Throat Assembly (Shown on page 20).**
(The unit will be received with the pumping chamber already mounted)

***5HP "Open Throat" Units (Sunburst, Gemini, Saturn); If applicable, the Supplemental Float must be mounted to the Main Float before installing on Unit (See Below).**

A. Supplemental Float Assembly
***If the Supplemental Float is already mounted to the Main Float, continue with main float assembly below.**
1. Place Main Float top face down.
2. Place the Supplemental Float on the Main Float as shown in the photo below.
3. Ty-Rap the floats together in four places (1 in each pocket).
4. Continue mounting Main Float.

B. Main Float Assembly
1. Stand the unit upright and place the float onto it so the holes in the float line up with the holes in the mounting brackets.
2. Place a fender washer onto a hex bolt and insert into one of the four holes in the float making sure it also goes through the hole in the steel mounting bracket on the unit. Repeat this for the three remaining holes.
3. Place a flat washer and a nylon locknut onto each of the four hex bolts. Tighten each nylon locknut.

CAUTION: Do not over tighten lock nuts, damage may occur to the float and/or pump chamber.

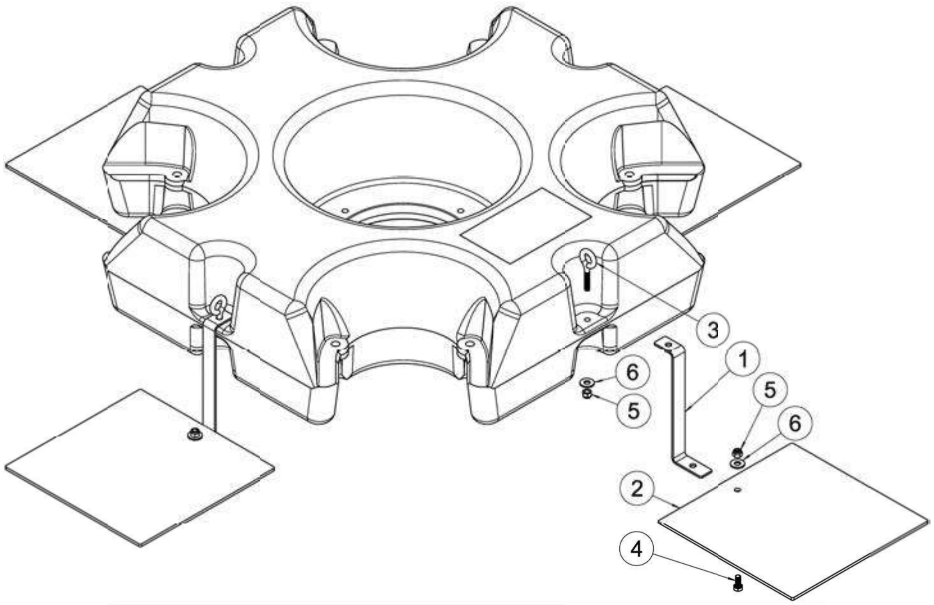



Fasten supplemental Float w/ Ty-Raps

Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Concept 3 Float	42-0018	1
	Float Mounting Hardware Kit (BELOW)	12-0071	1
2	M8x45 S/S Hex Bolt	22-0022	5
3	M8 Fender Washer	28-0008	5
4	M8 Flat Washer	28-0018	5
5	M8 Nylon Lock Nut	26-0007	5
6	Nylon Tie (NOT SHOWN)	GP5008	3

C. Mounting the Stabilizers (Comet Spray Pattern Only)

1. Mount each of the four stabilizer plates to the top side of a bracket using a hex bolt, a fender washer, and a nylon locknut as shown below.
2. Mount each of the four stabilizer plate assemblies from Step C1 to the top side of an outer hole in the float using an eyebolt, a fender washer, and a nylon locknut as shown. **Do not** over tighten. Damage may occur to the float.



Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
	Comet Stabilizer Plates Kit	12-0097	
1	Stabilizer Bracket	40-0115	4
2	Stabilizer Plate	41-0127	4
3	5/16-18x1-3/8" S/S Eyebolt	22-0027	4
4	5/16-18x3/4" S/S Hex Bolt	106-302	4
5	5/16-18 S/S Nylon Lock Nut	GP1208	8
6	5/16" Fender Washer	28-0008	8

D. Screen Installation

Debris Screens help to prevent clogging of the aerator and are available for all Otterbine aerators.

1. Place the unit upside down on blocks so the pump chamber does not get damaged.
2. Pull screen over motor unit until it reaches the lip on the float.
3. Make sure the cable/s are running through the bushing in the screen.
4. Fasten the screen to the lip on the float with the washers and screws provided so they are evenly spaced around the diameter.

Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
	1/4" Screen Kit	12-0075	1
	1/2" Screen Kit	12-0076	1
1	C3 Screen 1/4" 1/2"	 15-0022 15-0023	1
2	S/S Sheet Metal Screw	BP2803B	9
3	1" Fender Washer	800-011	9

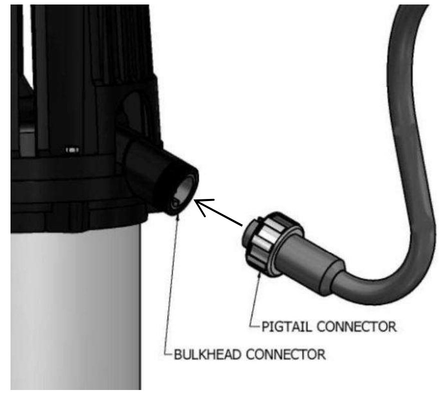
PHYSICAL INSTALLATION

WARNING: DISCONNECT POWER BEFORE INSTALLING, REMOVING, OR SERVICING UNIT

Concept 3 Otterbine aerators require **a minimum 30"/75cm (40"/100cm w/ lights)** of water depth.

A. Attach your Otterbine power cable to the aerator.

1. Align the keyway on the cable pigtail connector to the key on the aerator bulkhead connector and plug together. Thread the nut onto the bulkhead, hand tighten only, do not use tools on the pigtail connector nut.
Over tightening may cause the connector to fracture and possibly cause an electrical short circuit.



2. 5HP, 230V, 1 Phase units have a 3 pin bulkhead connector and a 3 pin pigtail connector on the power cable. All other ratings use 4 pin connectors.
3. A small amount of silicon compound has been factory applied to the female end of the aerator connector. The compound is necessary to make a waterproof seal between the two connectors. **DO NOT REMOVE COMPOUND!** When servicing the aerator re-apply compound. (Otterbine P/N: 48-0001).
4. **Install the cable strain relief device.** Pass the wire hoop from the strain relief through one of the holes in the float or around the float bracket. Reattach wire hoop to strain relief (see above).
5. For additional protection fasten the power cable, after the strain relief, to a float hole using the cable ties provided.

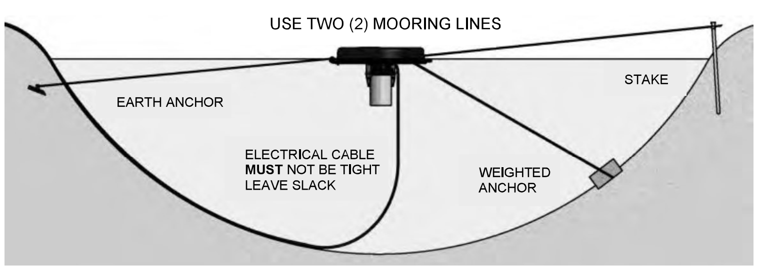
B. Pre-Startup Checks (To be performed by a qualified technician)

1. Factory connections may loosen during shipping. Verify tightness of all screw terminal connections before energizing.
2. Apply power to the PCC. Verify the incoming voltage is correct at the input terminals and matches the nameplate rating of the aerator. **For 115V & 230V Single Phase & Three Phase Units: The voltage between L1 on the input terminal block and the neutral terminal must measure a nominal 120V.**
3. Allowing the main door to be open and the swing panel door closed follow GFCI instructions on page 10 to reset aerator GFCI. Turn on disconnect and proceed.
4. With the aerator unit on the shore check for correct motor rotation. Briefly "bump" the M-O-A switch (Shown on Page 10) to "MAN" while observing the motor shaft rotation (turn on only long enough to establish operation and proper direction of rotation). **Aerator Shaft rotation MUST BE CCW looking at the top/impeller end of the unit**.

!TURN OFF DISCONNECT BEFORE PROCEEDING!

C. Fasten Mooring Lines and Launch

1. Mooring using stakes: Shore mounted stakes provides the easiest access to the aerator. Use stainless steel and/or brass hardware. Otterbine recommends using 1/4"(0.63cm) or 1/2"(1.25cm) polypropylene rope or stainless steel cable for mooring lines. At the mooring points use a wooden or metal stake or duck bill type earth anchors. Earth anchors allow the mooring lines to be hidden beneath the water surface. Drive the mooring stakes securely into the ground at the edge of the pond or place earth anchors close to the shore in the water. Fasten the mooring lines to opposite outer holes in the aerator float. Launch the aerator into the water, pull into the chosen location and fasten the lines to the stakes allowing slack for the aerator to twist up to 1/4 turn. The slack in the lines allows for movement during start up, fluctuations in the water level and wave action. Proceed to System Startup.
2. Mooring using Anchors: Use stainless steel and/or brass hardware. Otterbine recommends using 1/4"(0.63cm) or 1/2"(1.25cm) polypropylene rope or stainless steel cable for anchoring lines, use two 60 - 80 lb. (27 - 36 kilo) weights for anchors and a boat may be needed. Fasten the mooring lines to opposite outer holes in the float. Launch the aerator floating upside down (motor housing facing up). With the lines attached drop the anchors into the water at the predetermined locations. Adjust the lines to allow slack for the aerator up to 1/4 turn twist. The slack in the lines allows for movement during start up, fluctuations in the water level and wave action.



SYSTEM STARTUP

DO NOT ALLOW THE AERATOR TO OPERATE "DRY" OUT OF THE WATER

IMPORTANT: Otterbine aerators are designed to run in a Counterclockwise direction facing the top impeller end. Current unbalance for three phase systems shall not exceed 5%.
IMPORTANT: Aérateurs Otterbine sont conçus pour fonctionner dans le sens antihoraire regardant l'extrémité supérieure de la turbine. Courant de déséquilibre pour les trois systèmes de la phase ne doit pas dépasser 5%

A. User Control Functions

1. Disconnect Switch

DISCONNECT OFF
Removes Power to the Aerator for Maintenance/Servicing/Repair, Timers are not powered (Time of Day Needs to be Reset)

DISCONNECT ON
Power Applied, Mode of Operation Now Dependent on the Position of MOA Switch, Timers are Operating

DISCONNECT TRIPPED
Indicates a Ground Fault Motor/Wiring Short Circuit Or Motor Current Overload

2. MANUAL-OFF-AUTO switch.

M-O-A IN OFF
Aerator & Lighting Will Not Function, Timers are Powered and Operating, GFCI's may be Reset

M-O-A IN AUTO
Allows Automatic Control of Aerator & Lighting by Timers & Other Control Options

M-O-A IN MANUAL
Turns on Aerator, Bypasses Timer & Non-Critical Control Functions

3. GFCI (Ground Fault Circuit Interrupter) operation.
Enable **Aerator GFCI** first:
a. Power must first be applied to PCC.
b. Turn M-O-A switch to the off (center) position.
c. Press the RESET (ON) button, the green light will come on.
d. Turn disconnect switch clockwise to on (vertical).

CAUTION – UNIT WILL START IF M-O-A IS NOT SET TO OFF.

Enable **Lighting GFCI**:
a. With power to the PCC and the disconnect switch on. Press the reset button.

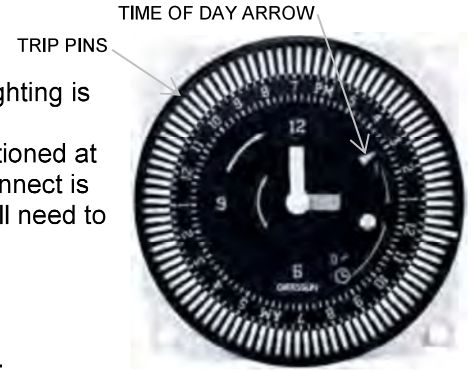
When loss of power to the PCC occurs the aerator will not re-start automatically when power is restored and the aerator GFCI will need to be reset.

Test all GFCI's every 6 months by pressing the TEST (OFF) button.
When testing the aerator GFCI the GREEN light should be on, press "TEST", the red light should turn on, the motor controller should trip and the disconnect handle should be off (horizontal at swing panel).

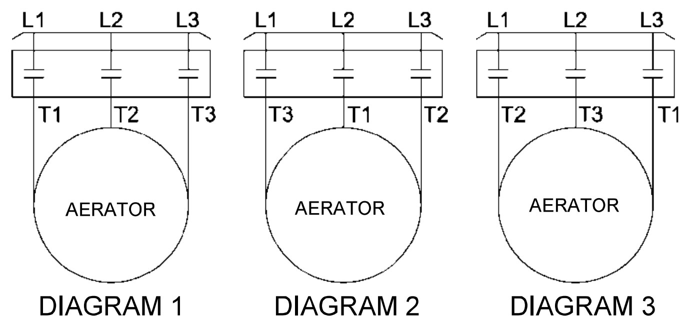
AERATOR GFCI

LIGHTING GFCI

4. Timer operation.
a. Start with all trip pins towards the center of the timer dial.
b. Push out from the center all trip pins that are between the times the aerator or lighting is to operate.
c. Turn the outer dial clockwise to align the time of day to the stationary arrow positioned at “2 o’clock”. Close the panel and turn the main disconnect on. When the main disconnect is off or in the case of power failure the timer/s will not operate and the time of day will need to be reset.
d. Timer control of the unit and lighting is enabled when in AUTO.



B. Energizing the Unit (To be performed by a qualified technician)
1. Single Phase Units: Motor rotation is factory determined and not field adjustable.
2. Three Phase Units: Verify correct motor rotation (Counter Clockwise looking at the top/impeller end of the unit). Check current readings on each phase. Verify three phase operating currents are balanced within 5%.
To calculate the percent of current unbalance:
Determine the Average Current:
a. Measure each of the three phase currents
b. Add the three phase amperage values together.
c. Divide the sum by three.
d. This is the average current value.
Determine Current Unbalance:
a. Select the phase current with the greatest difference from the average (calculated above).
b. Determine the difference between this phase current and the average current value.
c. Divide the difference by the average.
d. Multiply the result by 100 to determine percent of unbalance.
3. Use connection diagram 1, 2 or 3 at right which results in the lowest current unbalance. Roll the motor cable leads on the aerator output terminal block in the same direction to avoid motor reversal.
If the current unbalance is not corrected by rolling leads, locate the source of the unbalance and correct it.
a. If the phase farthest from the average stays on the same power lead after being moved the primary cause of unbalance is the power source.
b. If the phase farthest from the average moves on each of the connections with a particular motor lead, then the primary cause of unbalance is the "motor side" of the circuit.



Consider: damaged cable, leaking splice, poor connection, or a faulty motor as possible causes.
4. Once the unit is operational record the operating voltage, amperage, power control center serial number, power cable length and cable gauge on the label inside the power control panel.

MAINTENANCE

For Warranty Consideration Work Must Be Performed By an Authorized Service Facility

A. Keep the pumping chamber components and screen free of debris. Damage can occur to a clogged aerator.
B. Once a year, disconnect the unit from the power source and physically inspect the aerator, float and electrical cable. Visible damage to the motor unit or cable should be repaired to avoid safety hazards and/or potential failure.
C. Every three years, an oil change using “Otterbine Oil” is recommended to keep your aerator operating smoothly.

When a unit is properly cared for, it will give you years of trouble free service.

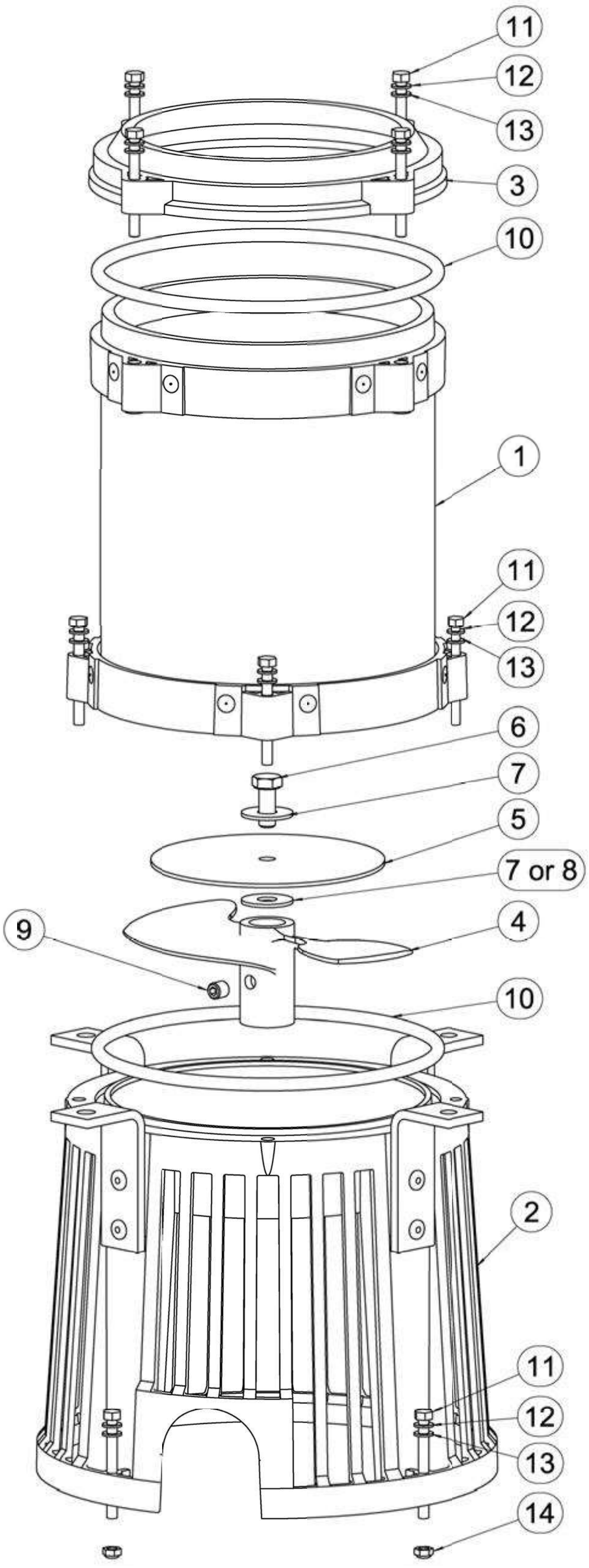
For Service, Repairs or Parts, Contact Your Local Otterbine Distributor
or
Call Otterbine Directly at 1-800-237-8837.

WINTERIZATION

Damage caused to the motor due to freezing will not be covered under warranty

In locations with extended periods of freezing temperatures the aerator may become frozen into the water possibly causing damage. Otterbine recommends the following Concept 3 units be removed from the water during freezing temperatures: ROCKET, PHOENIX, TRI-STAR, CONSTELLATION, COMET, GENESIS, EQUINOX, and OMEGA.
The GEMINI, SATURN, and SUNBURST pump higher volumes of water which helps to keep the water around the aerator from freezing. 24 hour a day operation will further decrease the opportunity for the unit to freeze in, although during periods of extremely cold temperatures this will not prevent the water from freezing.

SUNBURST PUMP CHAMBER

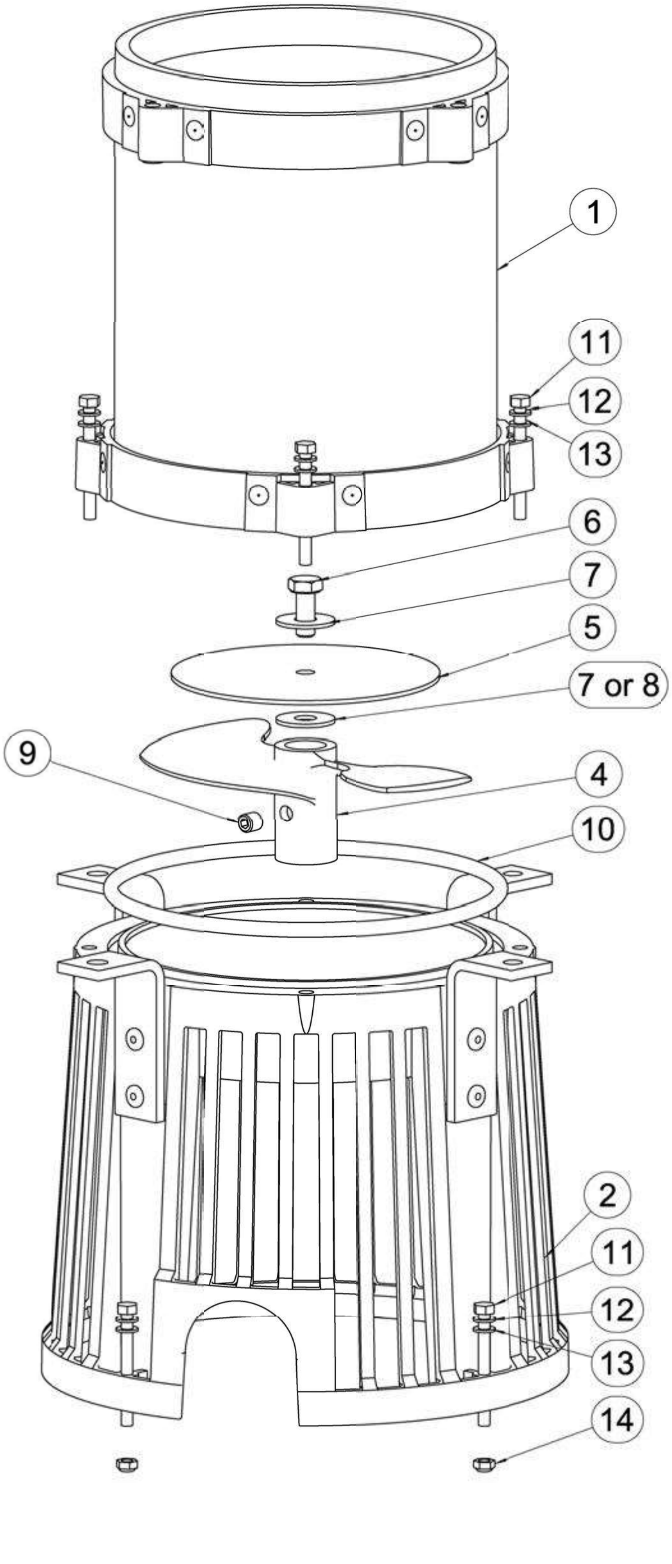


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Sunburst Ring	42-0019	1
4	Sunburst Impeller 1HP, 60Hz 2HP, 60Hz 3HP, 60Hz 5HP, 60Hz	 50-0012-001 50-0012-002 50-0012-003 50-0012-005	1
5	Slinger Disc	47-0003	1
6	M8x20 S/S Hex Bolt	22-0019	1
7	M8 (5/16") S/S Fender Washer (3HP Spacer)	28-0008	1
8	M8 (5/16") S/S Fender Washer (5HP Spacer)	40-0107	1
9	M8x8 S/S Set Screw	24-0015	1
10	O-ring #260	49-0015	2
11	M5x50 S/S Hex Bolt	24-0013	12
12	M5 S/S Split Lock Washer	28-0017	12
13	M5 S/S Flat Washer	28-0016	12
14	M5 S/S Nylon Locknut	26-0006	4

Sunburst Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Slide the Impeller onto the motor shaft so the top of the hub is even with the top of the shaft. Tighten the set screw onto one of the flats on the shaft.
3. Mount the Slinger Disc to the shaft using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Fender Washer. An Impeller Spacer is ONLY used with 3HP 60Hz/2HP 50Hz, 5HP 60Hz/3HP 50Hz, and 5HP 50Hz impellers (Item No. 7 or 8). Tighten the bolt to 35 ft-lbs (47 N-m).
4. Place an O-ring in the groove on the top of the Standoff Strainer Assembly.
5. Mount the Throat Assembly to the Standoff Strainer Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.
6. Place an O-ring on the top of the Throat Assembly.
7. Mount the Sunburst Ring to the Throat Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.

GEMINI PUMP CHAMBER

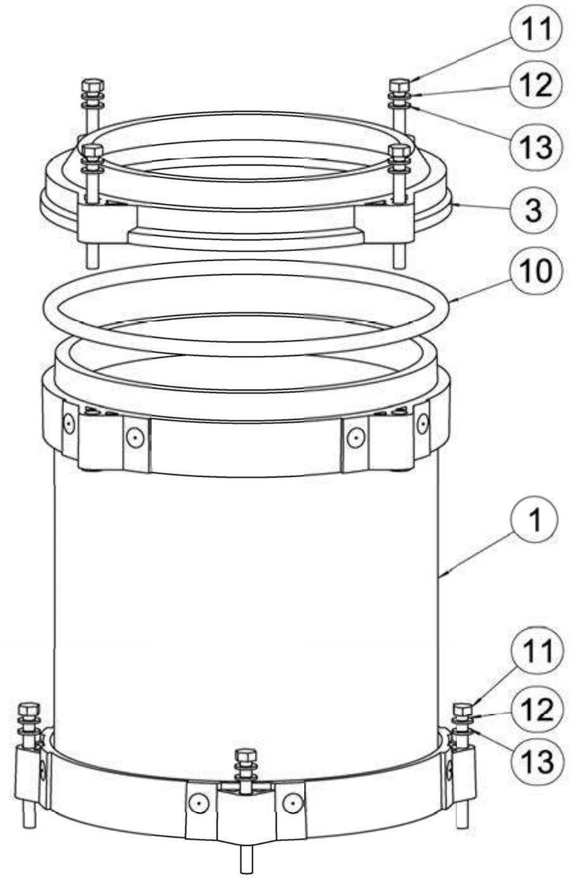


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
4	Sunburst Impeller 1HP, 60Hz 2HP, 60Hz 3HP, 60Hz 5HP, 60Hz	 50-0012-001 50-0012-002 50-0012-003 50-0012-005	1
5	Slinger Disc	47-0003	1
6	M8x20 S/S Hex Bolt	22-0019	1
7	M8 (5/16") S/S Fender Washer (3HP Spacer)	28-0008	1
8	M8 (5/16") S/S Fender Washer (5HP Spacer)	40-0107	1
9	M8x8 S/S Set Screw	24-0015	1
10	O-ring #260	49-0015	1
11	M5x50 S/S Hex Bolt	24-0013	8
12	M5 S/S Split Lock Washer	28-0017	8
13	M5 S/S Flat Washer	28-0016	8
14	M5 S/S Nylon Locknut	26-0006	4

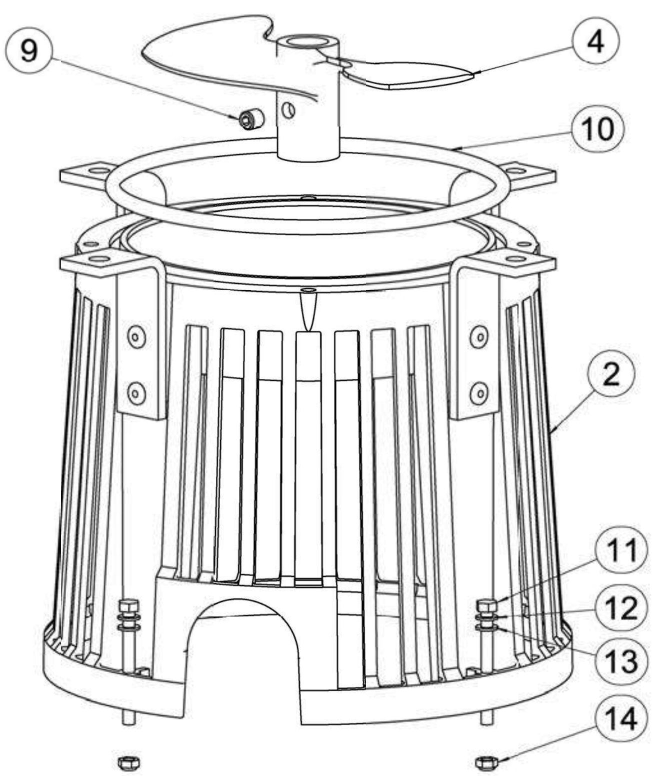
Gemini Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Slide the Impeller onto the motor shaft so the top of the hub is even with the top of the shaft. Tighten the set screw onto one of the flats on the shaft.
3. Mount the Slinger Disc to the shaft using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Fender Washer. An Impeller Spacer is ONLY used with 3HP 60Hz/2HP 50Hz, 5HP 60Hz/3HP 50Hz, and 5HP 50Hz impellers (Item No. 7 or 8). Tighten the bolt to 35 ft-lbs (47 N-m).
4. Place an O-ring in the groove on the top of the Standoff Strainer Assembly.
5. Mount the Throat Assembly to the Standoff Strainer Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.

SATURN PUMP CHAMBER



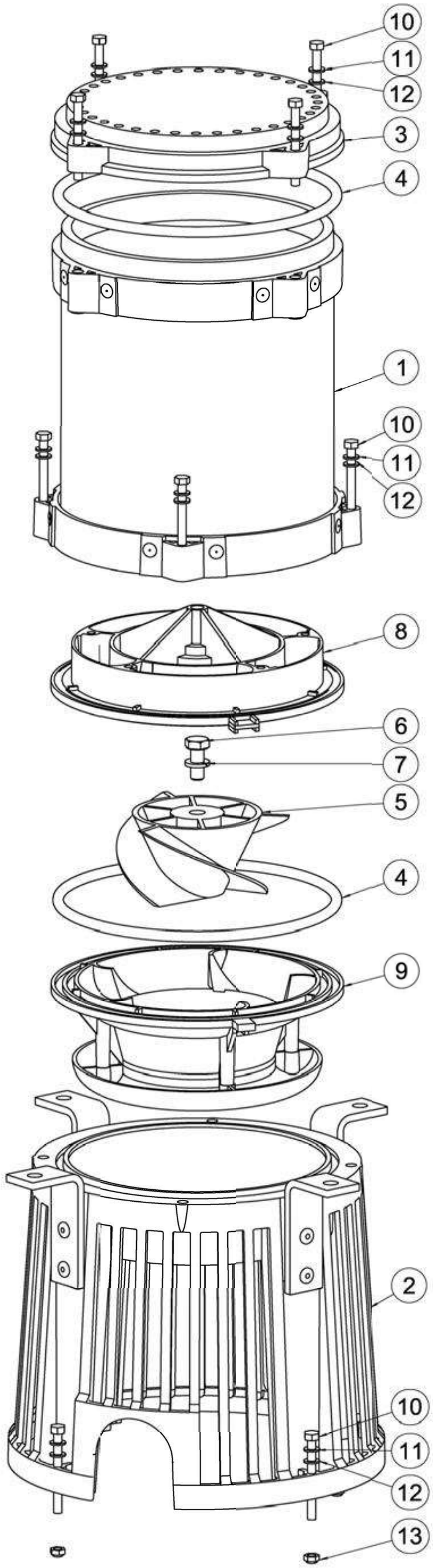
Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Sunburst Ring	42-0019	1
4	Sunburst Impeller		1
	1HP, 60Hz	50-0012-001	
	2HP, 60Hz	50-0012-002	
	3HP, 60Hz	50-0012-003	
	5HP, 60Hz	50-0012-005	
5	Slinger Disc	47-0003	1
9	M8x8 S/S Set Screw	24-0015	1
10	O-ring #260	49-0015	2
11	M5x50 S/S Hex Bolt	24-0013	12
12	M5 S/S Split Lock Washer	28-0017	12
13	M5 S/S Flat Washer	28-0016	12
14	M5 S/S Nylon Locknut	26-0006	4



Saturn Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Slide the Impeller onto the motor shaft so the top of the hub is even with the top of the shaft. Tighten the set screw onto one of the flats on the shaft.
3. Place an O-ring in the groove on the top of the Standoff Strainer Assembly.
4. Mount the Throat Assembly to the Standoff Strainer Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.
5. Place an O-ring on the top of the Throat Assembly.
6. Mount the Sunburst Ring to the Throat Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.

ROCKET PUMP CHAMBER

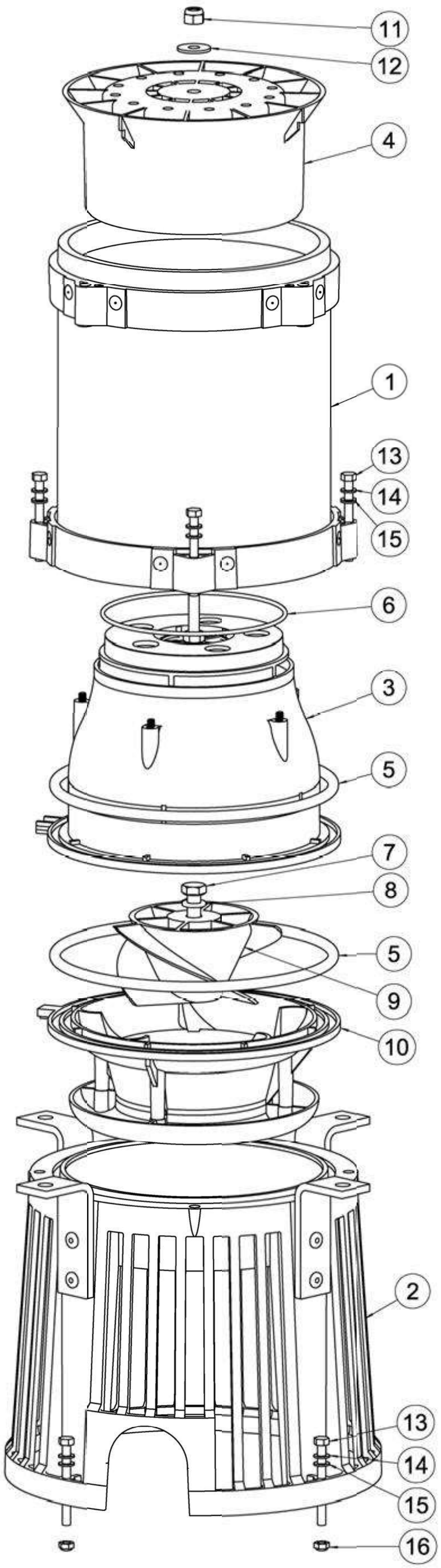


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Rocket Diffuser	41-0104	1
4	O-ring #260	49-0015	3
5	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
6	M8x20 S/S Hex Bolt	22-0019	1
7	M8 (5/16") S/S Split Lock Washer	28-0019	1
8	Upper Pump Chamber	42-0023	1
9	Lower Pump Chamber Assembly	10-0065	1
10	M5x50 S/S Hex Bolt	24-0013	12
11	M5 S/S Split Lock Washer	28-0017	12
12	M5 S/S Flat Washer	28-0016	12
13	M5 S/S Nylon Locknut	26-0006	4
14	Decorative Impeller Shim (not shown)	40-0099	1,2,or3

Rocket Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 (Item 14) Shims as necessary onto the end of the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber.
5. Place the Upper Pump Chamber onto the Lower Pump Chamber Assembly so the tabs on each part align. NOTE: If these tabs do not align the pump will not function properly.
6. Place an O-ring in the groove of the Upper Pump Chamber.
7. Place the Throat Assembly onto the Upper Pump Chamber and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-rings.
8. Place an O-ring on the top of the Throat Assembly.
9. Mount the Rocket Diffuser to the Throat Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.

PHOENIX PUMP CHAMBER

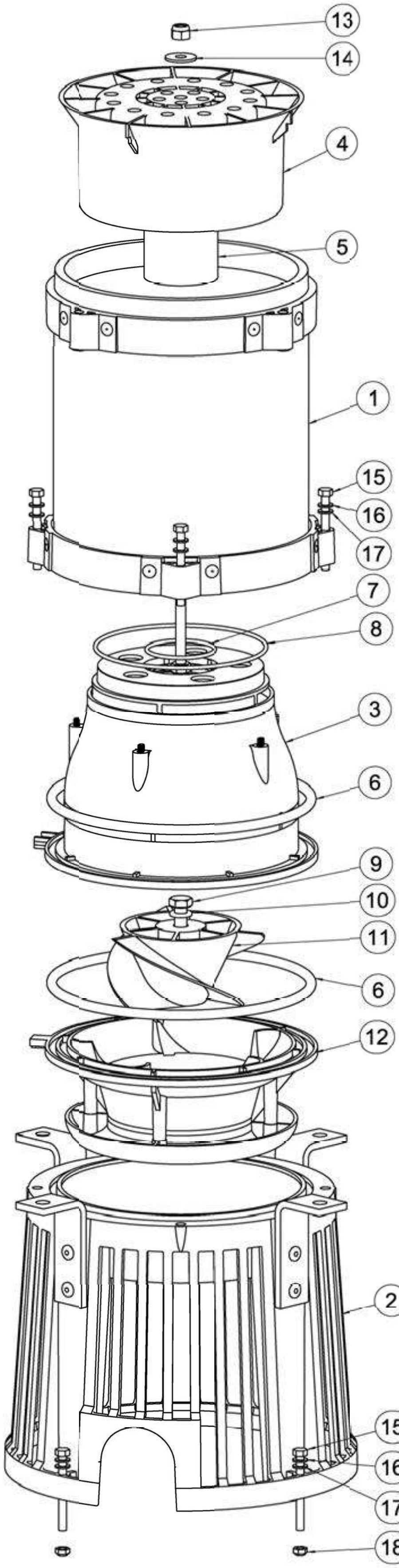


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Phoenix/Tri-Star Flow Diverter	10-0062	1
4	Phoenix Diffuser	41-0105	1
5	O-ring #260	49-0015	2
6	O-ring #156	49-0018	1
7	M8x20 S/S Hex Bolt	22-0019	1
8	M8 (5/16") S/S Split Washer	28-0019	1
9	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
10	Lower Pump Chamber	10-0065	1
11	M8 S/S Nylon Locknut	26-0007	1
12	M8 (5/16") S/S Flat Washer	28-0018	1
13	M5x50 S/S Hex Bolt	24-0013	8
14	M5 S/S Split Lock Washer	28-0017	8
15	M5 S/S Flat Washer	28-0016	8
16	M5 S/S Nylon Locknut	26-0006	4
17	Decorative Impeller Shim (not shown)	40-0099	1,2or3

Phoenix Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 Shims (Item 17) as necessary onto the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber.
5. Place the Phoenix/Tri-Star Flow Diverter Assembly onto the Lower Pump Chamber Assembly so the tabs on each part align. NOTE: If these tabs do not align the pump will not function properly.
6. Place an O-ring in the groove of the Upper Pump Chamber.
7. Place the Throat Assembly onto the Upper Pump Chamber and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.
8. Place an O-ring on the top of the Flow Diverter.
9. Slide the Phoenix Diffuser onto the Carriage Bolt until seated on the Flow Diverter Assembly and secure using a M8 S/S Flat Washer and a M8 S/S Nylon Locknut. Center the Diffuser on the Throat Assembly, tighten the locknut (11). Do not over tighten, may cause damage.

TRI-STAR PUMP CHAMBER

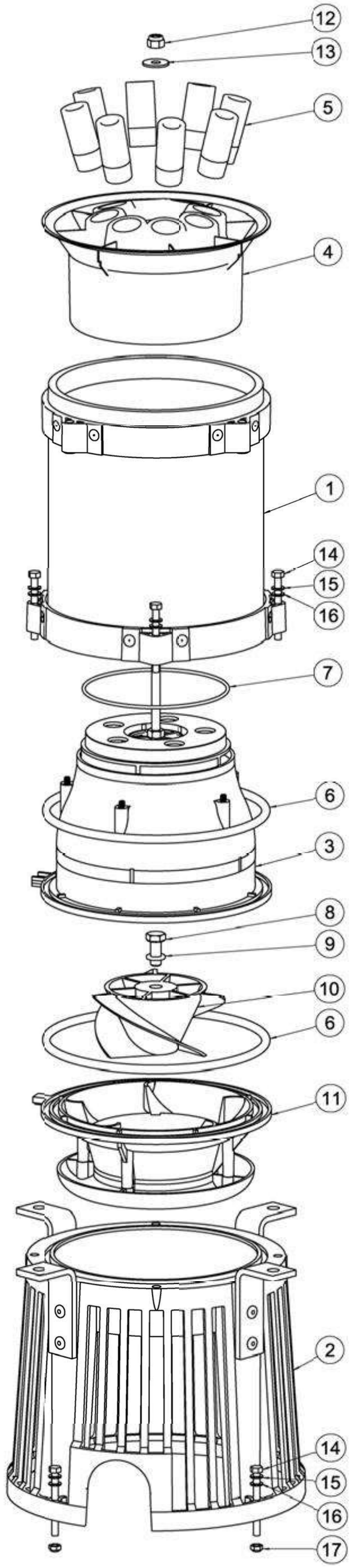


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Phoenix/Tri-Star Flow diverter	10-0062	1
4	Tri-Star Diffuser	41-0106	1
5	Tri-Star Diffuser Pipe	41-0108	1
6	O-ring #260	49-0015	2
7	O-ring #131	49-0017	1
8	O-ring #156	49-0018	1
9	M8x20 S/S Hex Bolt	22-0019	1
10	M8 (5/16") S/S Split Washer	28-0019	1
11	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
12	Lower Pump Chamber	10-0065	1
13	M8 S/S Nylon Locknut	26-0007	1
14	M8 (5/16") S/S Flat Washer	28-0018	1
15	M5x50 S/S Hex Bolt	24-0013	8
16	M5 S/S Split Lock Washer	28-0017	8
17	M5 S/S Flat Washer	28-0016	8
18	M5 S/S Nylon Locknut	26-0006	4
19	Decorative Impeller Shim (not shown)	40-0099	1,2or3

Tri-Star Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 Shims (Item 19) as necessary onto the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber.
5. Place the Phoenix/Tri-Star Flow Diverter Assembly onto the Lower Pump Chamber Assembly so the tabs on each part align. NOTE: If these tabs do not align the pump will not function properly.
6. Place an O-ring in the groove of the Upper Pump Chamber.
7. Place the Throat Assembly onto the Upper Pump Chamber and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-rings.
8. Place two (2) o-rings on the top inside & outside of the Flow Diverter.
9. Place the Tri-Star Diffuser Pipe in the Flow Diverter Assembly so it rests on the O-ring.
10. Slide the Tri-Star Diffuser onto the Carriage Bolt until seated on the Flow Diverter Assembly/Tri-Star Diffuser Pipe, secure using an M8 S/S Flat Washer and an M8 S/S Nylon Locknut. Center the Diffuser on the Throat Assembly, tighten the locknut (13). Do not over tighten, may cause damage.

CONSTELLATION PUMP CHAMBER

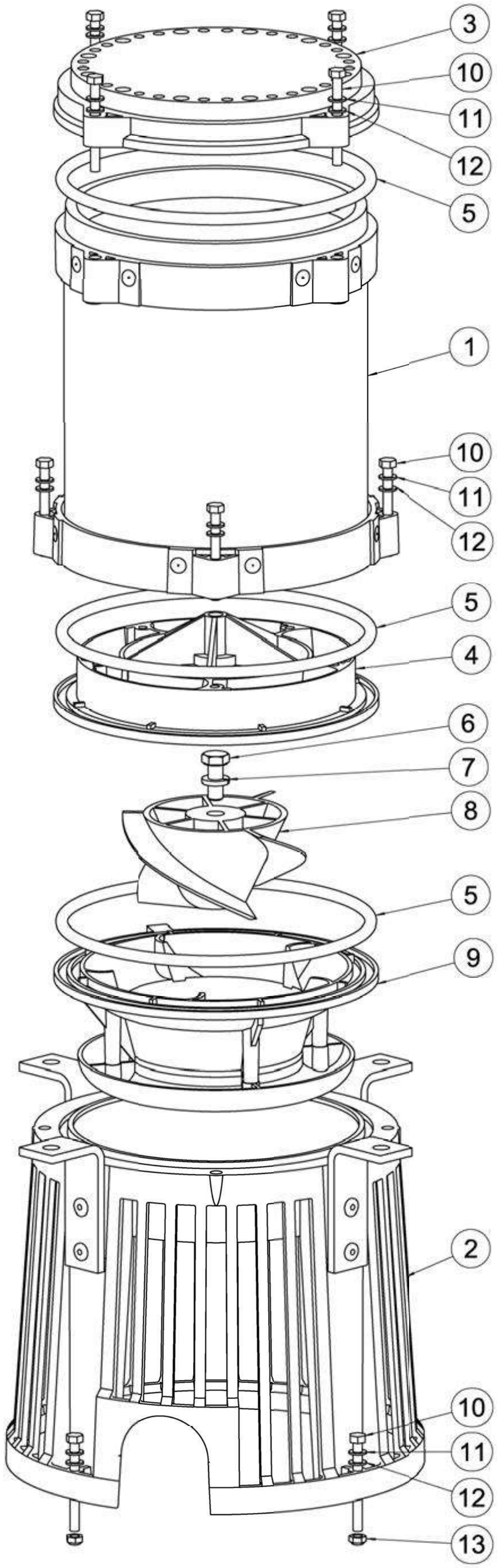


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Constellation Flow Diverter	10-0069	1
4	Constellation Diffuser	42-0032	1
5	Constellation Nozzle	10-0068	1
6	O-ring #260	49-0015	2
7	O-ring #156	49-0018	1
8	M8x20 S/S Hex Bolt	22-0019	1
9	M8 (5/16") S/S Split Washer	28-0019	1
10	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
11	Lower Pump Chamber	10-0065	1
12	M8 S/S Nylon Locknut	26-0007	1
13	M8 (5/16") S/S Flat Washer	28-0018	1
14	M5x50 S/S Hex Bolt	24-0013	8
15	M5 S/S Split Lock Washer	28-0017	8
16	M5 S/S Flat Washer	28-0016	8
17	M5 S/S Nylon Locknut	26-0006	4
18	Decorative Impeller Shim (not shown)	40-0099	1,2or3

Constellation Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 Shims (Item 18) as necessary onto the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber.
5. Place the Constellation Flow Diverter Assembly onto the Lower Pump Chamber Assembly so the tabs on each part align. NOTE: If these tabs do not align the pump will not function properly.
6. Place an O-ring in the groove of the Upper Pump Chamber.
7. Place the Throat Assembly onto the Upper Pump Chamber and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.
8. Place an O-ring on the top of the Flow Diverter Assembly.
9. Slide the Constellation Diffuser onto the Carriage Bolt until seated on the Flow Diverter Assembly. Secure using an M8 S/S Flat Washer and S/S Nylon Locknut. Center the Diffuser on the Throat Assembly. Tighten the locknut. Do not over tighten, may cause damage.
10. Thread a Constellation Nozzle into one of the holes in the Galaxy Diffuser and tighten (DO NOT OVER TIGHTEN, MAY CAUSE DAMAGE). Repeat for the remaining seven Galaxy Nozzles. NOTE: Place Teflon tape on the threads of the Constellation Nozzle.

COMET PUMP CHAMBER

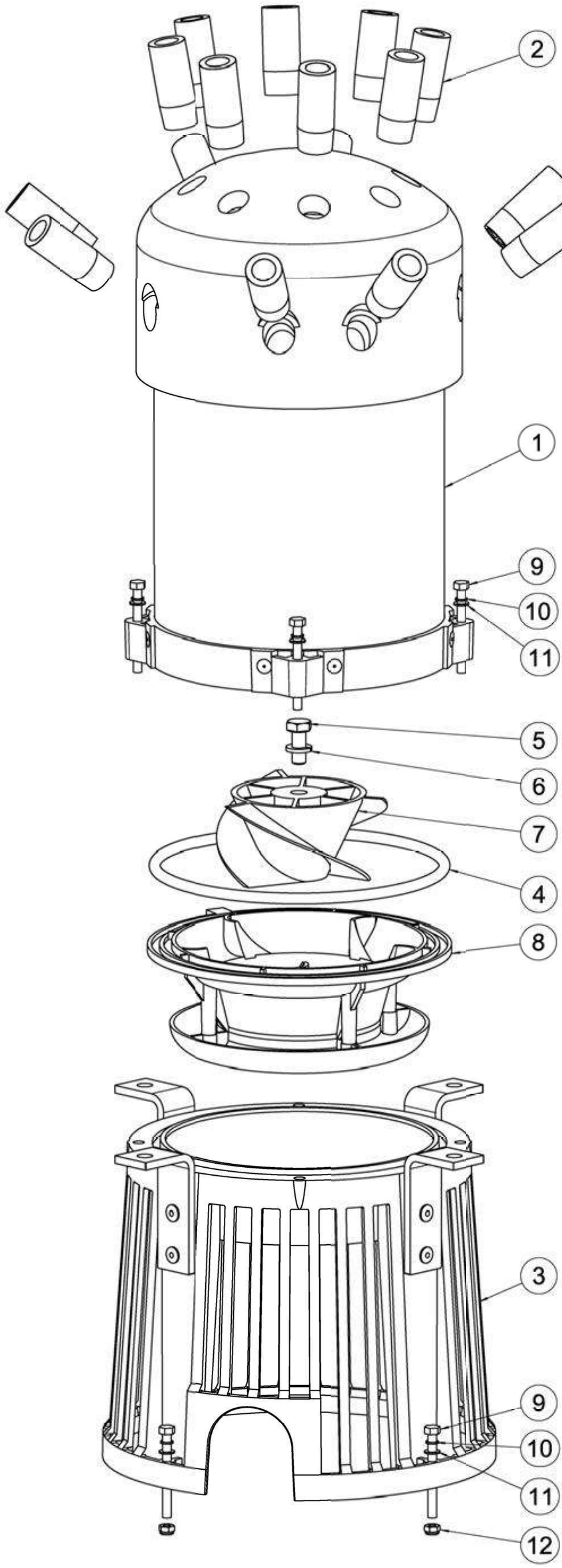


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Throat Assembly	10-0060	1
2	Standoff Strainer Assembly	10-0061	1
3	Comet Diffuser	41-0123	1
4	Upper Pump Chamber	42-0023	1
5	O-ring #260	49-0015	3
6	M8x20 S/S Hex Bolt	22-0019	1
7	M8 (5/16") S/S Split Washer	28-0019	1
8	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
9	Lower Pump Chamber	10-0065	1
10	M5x50 S/S Hex Bolt	24-0013	12
11	M5 S/S Split Lock Washer	28-0017	12
12	M5 S/S Flat Washer	28-0016	12
13	M5 S/S Nylon Locknut	26-0006	4
14	Decorative Impeller Shim (not shown)	40-0099	1,2,or3

Comet Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 Shims (Item 14) as necessary onto the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber.
5. Place the Upper Pump Chamber onto the Lower Pump Chamber Assembly so the tabs on each part align. NOTE: If these tabs do not align the pump will not function properly.
6. Place an O-ring in the groove of the Upper Pump Chamber.
7. Place the Throat Assembly onto the Upper Pump Chamber and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.
8. Place an O-ring on the top of the Throat Assembly.
9. Mount the Comet Diffuser to the Throat Assembly using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring.

GENESIS PUMP CHAMBER



Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Genesis Throat Assembly	10-0073	1
2	Genesis Nozzle	10-0068	16
3	Standoff Strainer Assembly	10-0061	1
4	O-ring #260	49-0015	1
5	M8x20 S/S Hex Bolt	22-0019	1
6	M8 (5/16") S/S Split Washer	28-0019	1
7	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
8	Lower Pump Chamber	10-0065	1
9	M5x50 S/S Hex Bolt	24-0013	8
10	M5 S/S Split Lock Washer	28-0017	8
11	M5 S/S Flat Washer	28-0016	8
12	M5 S/S Nylon Lock Nut	26-0006	4
13	Decorative Impeller Shim (not shown)	40-0099	1,2,or3

Genesis Assembly Instructions

1. Mount the Standoff Strainer Assembly to the power unit using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, (4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.

2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.

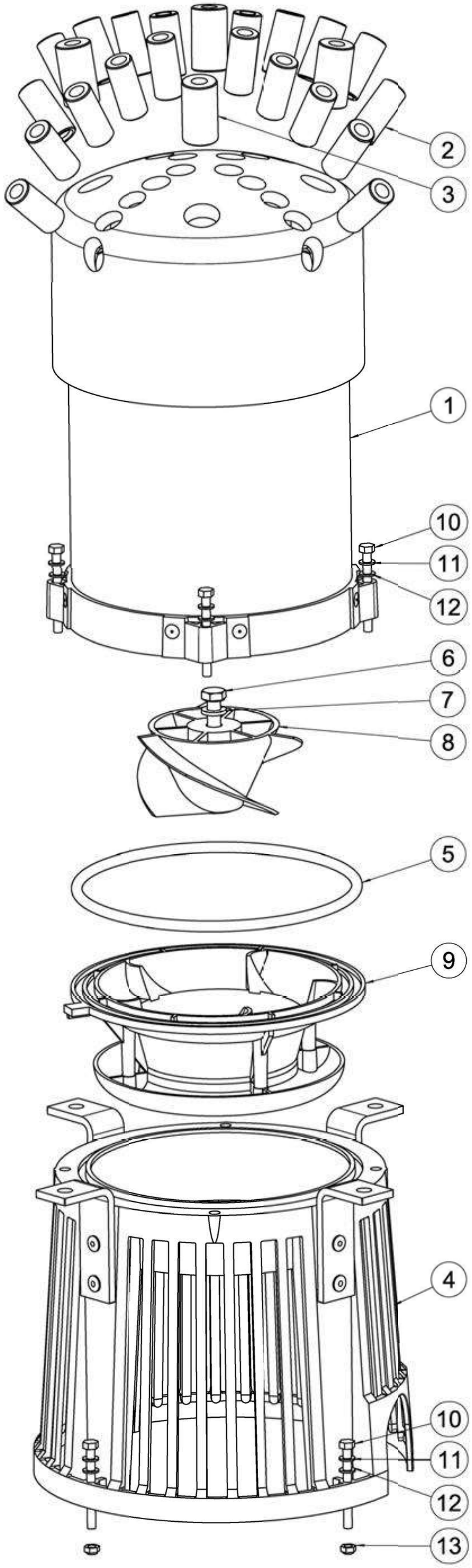
3. Slide the Impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly place 1, 2 or 3 Shims (Item 13) as necessary onto the shaft to raise the Impeller so it no longer rubs. Secure using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.

4. Place an O-ring in the groove of the Lower Pump Chamber Assembly.

5. Place the Genesis Throat Assembly onto the Lower Pump Chamber Assembly and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring. NOTE: The Float must be mounted before the Genesis Throat Assembly is installed (See Float Mounting Instructions).

6. Thread a Genesis Nozzle into one of the holes in the Galaxy Diffuser and tighten (DO NOT OVERTIGHTEN, MAY CAUSE DAMAGE). Repeat for the remaining fifteen Genesis Nozzles. NOTE: Place Teflon tape on the threads of the Genesis Nozzle.

EQUINOX PUMP CHAMBER

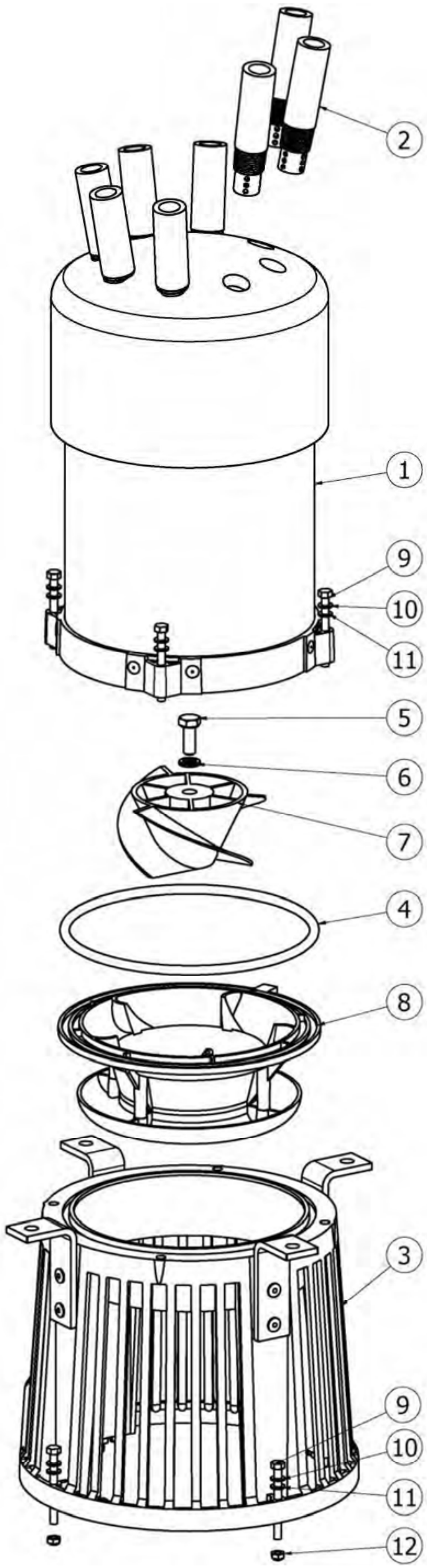


Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Equinox Throat Assembly	10-0008	1
2	1/2"NPT x 1-1/2" Nozzle	41-0023	20
3	3/8"NPT x 1-1/2" Nozzle	41-0022	4
4	Standoff Strainer Assembly	10-0061	1
5	O-ring #260	49-0015	1
6	M8x20 S/S Hex Bolt	22-0019	1
7	M8 (5/16") S/S Split Washer	28-0019	1
8	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
9	Lower Pump Chamber	10-0065	1
10	M5x50 S/S Hex Bolt	24-0013	8
11	M5 S/S Split Lock Washer	28-0017	8
12	M5 S/S Flat Washer	28-0016	8
13	M5 S/S Nylon Lock Nut	26-0006	4
14	Decorative Impeller Shim (not shown)	40-0099	1,2,or3

Equinox Assembly Instructions

1. Mount Standoff Strainer Assembly to the power unit using (7) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers,(4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Place a shim (Item 14) on the top of the motor shaft prior to installing the impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly add another shim (do not use more than four (4) shims). Secure impeller using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber Assembly.
5. Place the Equinox Throat Assembly onto the Lower Pump Chamber Assembly and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring. NOTE: The Float must be mounted before the Equinox Throat Assembly is installed (See Float Mounting Instructions).
6. If replacing nozzles on the Equinox throat assembly place Teflon tape on the threads of the nozzle and DO NOT OVERTIGHTEN, THE THROAT MAY BE DAMAGED.

OMEGA PUMP CHAMBER



Parts List			
ITEM	DESCRIPTION	PART NUMBER	QTY
1	Omega Throat Assembly	10-0053	1
2	Omega Nozzle	41-0115	8
3	Standoff Strainer Assembly	10-0061	1
4	O-ring #260	49-0015	1
5	M8x20 S/S Hex Bolt	22-0019	1
6	M8 (5/16") S/S Split Washer	28-0019	1
7	Decorative Impeller		1
	1HP, 60Hz	50-0010-001	
	2HP, 60Hz	50-0010-002	
	3HP, 60Hz	50-0010-003	
	5HP, 60Hz	50-0010-005	
8	Lower Pump Chamber	10-0065	1
9	M5x50 S/S Hex Bolt	24-0013	8
10	M5 S/S Split Lock Washer	28-0017	8
11	M5 S/S Flat Washer	28-0016	8
12	M5 S/S Nylon Lock Nut	26-0006	4
13	Decorative Impeller Shim (not shown)	40-0099	1,2,or3

Omega Assembly Instructions

1. Mount Standoff Strainer Assembly to the power unit using (7) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers,(4) M5 S/S Split Lock Washers, and (4) M5 S/S Hex Nylon Locknuts. Tighten the screws evenly. NOTE: Standoff Strainer Assembly is not part of the Pump Chamber Assembly.
2. Place the Lower Pump Chamber Assembly into the Standoff Strainer Assembly.
3. Place a shim (Item 14) on the top of the motor shaft prior to installing the impeller onto the motor shaft. If the Impeller rubs against the inside wall of the Lower Pump Chamber Assembly add another shim (do not use more than four (4) shims). Secure the impeller using (1) M8x20 S/S Hex Bolt and (1) M8 S/S Split Lock Washer. Tighten the bolt.
4. Place an O-ring in the groove of the Lower Pump Chamber Assembly.
5. Place the Omega Throat Assembly onto the Lower Pump Chamber Assembly and secure using (4) M5x50 S/S Hex Screws, (4) M5 S/S Flat Washers, and (4) M5 S/S Split Lock Washers. Tighten the screws evenly in order to properly compress the o-ring. NOTE: The Float must be mounted before the Omega Throat Assembly is installed (See Float Mounting Instructions).
6. If replacing nozzles on the Omega throat assembly place Teflon tape on the threads of the nozzle and DO NOT OVERTIGHTEN, THE THROAT MAY BE DAMAGED.

Limited 5 Year Warranty
Otterbine® Product

WARRANTY: Barebo, Inc 3840 Main Road East, Emmaus Pennsylvania 18049,U.S.A. hereby warrants, subject to the conditions herein below set forth, that should the **OTTERBINE** product prove defective by reason of improper workmanship or materials at any time during the warranty period the Purchaser at retail will be guarantee that **BAREBO** will repair or replace the said **OTTERBINE** product as may be necessary to restore it to satisfactory operating condition, without any charge for materials or labor necessarily incident to such repair or replacement, provided that:

a) The enclosed Warranty Registration Card should be mailed to **BAREBO** within fifteen (15) days of the original receipt by the Purchaser at retail in order to avoid delays:

b) The **OTTERBINE** product must be delivered or shipped, prepaid, in its original container or a container offering an equal degree of protection, to **BAREBO** or a facility authorized by **BAREBO** to render the said repair or replacement services or, if purchased from an authorized **OTTERBINE** dealer, to such dealer;

c) The **OTTERBINE** product must not have been altered, repaired or serviced by anyone other than **BAREBO**, a service facility authorized by **BAREBO** to render such service, or by an authorized **BAREBO** dealer, and the serial number of the **OTTERBINE** product must not have been removed or altered: and

d) The **OTTERBINE** product must not have been subjected to lightning strikes and other Acts of God, vandalism, freezing-in, accident, misuse or abuse, and must have been installed in conformance with applicable electrical codes (including proper electrical protection), and also installed, operated and maintained in accordance with guidelines in the Owner's Manual shipped with the Otterbine product.

e) The **OTTERBINE** product must be physically inspected on an annual basis to insure the unit, the connector and the power cable are not damaged and are in proper working condition.

No implied warranties of any kind are made by **BAREBO** in connection with this **OTTERBINE** product, and no other warranties, whether expressed or implied, including implied warranties of merchantability and fitness for a particular purpose, shall apply to this **OTTERBINE** product. Should this **OTTERBINE** product prove defective in workmanship or material, the retail Purchaser's sole remedy shall be repair or replacement as is hereinabove expressly provided and, under no circumstances, shall **BAREBO** be liable for any loss, damage or injury, direct or consequential, arising out of the use of, or inability to use, the **OTTERBINE** product, including but not limited to retail Purchaser's cost, loss of profits, goodwill, damages due to loss of product or interruption of service, or personal injuries to Purchaser or any person.

MODEL (circle one):				
	Sunburst	Gemini	Rocket	Phoenix
	Tri-Star	Saturn	Comet	Constellation
	Genesis	Omega	Equinox	

HORSEPOWER (circle one): 1 2 3 5

VOLTAGE (circle one): 115 230 208-230 380 415 460 575

PHASE (circle one): Single Three **HERTZ (circle one):** 50 60

CORD GAUGE & LENGTH____

UNIT SERIAL NUMBER ____

PANEL SERIAL NUMBER ____

OPTIONS____

Water Works With Otterbine!

Otterbine/Barebo, Inc.
3840 Main Rd. East
Emmaus, PA. 18049
U.S.A.

PHONE: 1-800-AER8TER (237-8837) or (610) 965-6018
FAX: (610) 965-6050
E-mail: aeration@otterbine.com
www.otterbine.com

Appendix D - Aspirating Aerator Literature

Tornado®

SURFACE ASPIRATING AERATOR

Powerful and reliable, self-aspirating surface Tornado aerators are used to upgrade lagoon systems and expand the treatment capacity of mechanical wastewater treatment plants.

Tornado surface aspirating aerators improve aeration and mixing in a wide range of applications.

Tornado provides high oxygen transfer and intensive mixing capabilities in a wide range of applications. The Tornado aerator's turbulent directional mixing and jet propulsion discharge assures that oxygen is quickly blended with the wastewater for unmatched oxygen transfer. The intense action of the jet propulsion shears wastewater solids to increase treatment performance and provide better contact for the oxygen and wastewater bacteria.

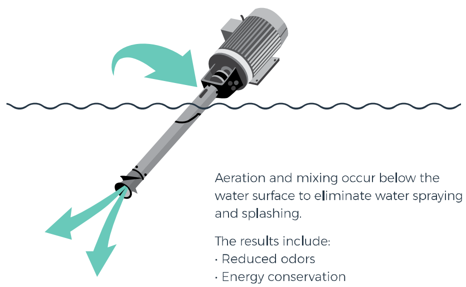
fluence™

Value from Water

Principle of Operation

The Tornado aerator mounts at an angle in the water with the motor and air intake above the surface and the propeller submerged below the water. The solid motor shaft spins a proprietary stainless steel propeller. Water moves at a high velocity through and near the propeller, creating a low pressure zone at the hub. The low pressure zone draws air in through the stationary intake and down the large diameter draft tube. The air exits into the water at the propeller hub. Turbulence and flow created by the propeller breaks up the air bubbles, mixes the basin, and disperses oxygen.

Air enters the Tornado through the opening in the draft tube



Aeration and mixing occur below the water surface to eliminate water spraying and splashing.

The results include:
· Reduced odors
· Energy conservation
· Icing problems eliminated

Key Technical Features

- Available horsepower range: 2-100 hp (1.5 kW-75 kW)
- Operational speed: 1800 rpm at 60 Hz (1500 rpm at 50 Hz)
- Premium efficiency (TEFC) motors
- 304 stainless steel (standard) or 316 stainless steel (optional) construction
- Grease-lubricated bearings and a solid shaft ensure a vibration-free design

Markets and Industries

- Municipal Wastewater Treatment
- Aquaculture
- Wineries & Breweries
- Chemical Processing
- Pulp & Paper Mills
- Textile
- Oil & Gas
- Mining
- Dairies
- Food & Beverage Processing

Suitable Applications

- Activated sludge basins
- Sludge holding tanks/digesters
- Oxidation ditches
- Lagoons
- Post Aeration
- Odor and algae control/air cap
- Ice control
- Leachate treatment

Rugged Construction

Harsh wastewater environments require tough, rugged materials designed for longevity and reliability in extreme environmental conditions. The Tornado's sealed, grease-lubricated bearings allow the aerators to be used in applications with high amounts of solids, grit, or sand and in leachate treatment. The two tapered roller bearings securely support the aerator shaft, preventing vibration and taking up all propeller thrust loads. The roller bearings are designed for up to 100,000 hours of service life. The unique self-heating bearing design allows the system to be installed in cold climates and operate year-round.

Stainless Steel Components

Durable stainless steel floats are unmatched in the industry and ensure the aerator remains buoyant for its full life, even in the harshest of environments. Proprietary engineering ensures that the aerator runs properly throughout its service life, without time-consuming maintenance.

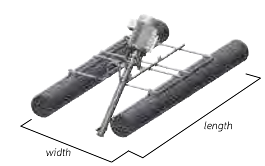
Reduced Energy Costs

Every Tornado aerator is equipped with a premium efficiency motor to reduce energy costs. Larger motors are designed to work with soft start or Variable Frequency Drive (VFD) controllers to eliminate power surge penalties and reduce energy costs.

Tornado® Specifications

hp	kW	60 Hz Motor rpm	Motor FLA 460V	50 Hz Motor rpm	Motor FLA 380 V	Ship Weight lb (kg)	Pontoon System Available
2	1.5	1730	3.1	1425	3.7	118 (54)	a, b
3	2	1745	4.0	1450	4.8	161 (73)	a, b
5	4	1750	6.5	1445	7.9	169 (76)	a, b
7.5	5.5	1750	9.4	1445	11.6	225 (102)	a, b
10	7.5	1750	12.4	1445	15	248 (113)	a, b
15	11	1760	18.6	1450	22.6	407 (185)	b, c
20	15	1760	23.5	1450	31.4	492 (223)	b ,c
25	18.5	1770	29.6	1460	35.2	539 (244)	b, c
30	22	1770	35.5	1460	42	541 (245)	b, c
40	30	1770	47.1	1460	55	730 (331)	b, c
50	37	1770	59.2	1460	68	914 (415)	c, d
60	45	1775	69.4	1465	83	1146 (520)	c, d
75	56	1775	86.2	1465	103.5	1219 (553)	d
100	74.5	1780	114	1480	135	1353 (1353)	d

Pontoon System	Length in (cm)	Width in (cm)
2-Float (a)	72 (183)	70 (177)
4-Float (b)	145 (368)	70 (177)
6-Float (c)	145 (368)	105 (267)
8-Float (d)	145 (368)	105 (267)



fluence™

Available Accessories

- Anti-erosion shields to prevent erosion in shallow (clay or earthen) basins
- Anti-vortex shield if vortexing occurs or if an aerator is operated below the standard 45 degree angle of operation
- Low-level legs to prevent damage to basin or equipment when waterlevels drop below three feet
- Walls and bridge mounts for mounting flexibility
- Swing arms to accommodate up to 15 feet of fluctuations in water elevation
- Maintenance decks built on pontoon platforms for easy servicing access
- Automatic grease lubrication equipment to reduce maintenance
- Blower add-on kit accessory to convert to blower-assisted operation

Rental units also available

The Blower Assisted TORNADO Aerator is used for wastewater treatment applications that require a higher level of oxygenation. A blower is added to the self-aspirating aerator to force additional air down the inlet hole. The blower uses a small motor, typically from 2 to 10 HP (1.5kW to 7.5 kW), that inputs more oxygen as compared to a standard Tornado aerator. The Tornado Blower-assist aerator mounts at an angle on floats or can be wall-mounted. The motor and air intake is above the surface and the propeller is submerged beneath the water.

Fluence is Your EXPERT

With thousands of installed units around the world, Fluence is your expert provider for wastewater treatment solutions. We offer all major wastewater aeration technologies and the expertise to help you select and apply the equipment best suited for your application. Our technical experts are ready to assist you with the proper sizing, layout, and operation of your aeration system.

From:	Dina Palumbo
To:	Kevin Cassidy
Subject:	TORNADO aerator by Fluence
Date:	Wednesday, November 4, 2020 9:06:36 PM
Attachments:	image001.png Tornado_Brochure.pdf 07-17 - TORNADO Specifications.docx 07-17 - TORNADO Float Specs.docx 100 Hp Tornado on 8 float system.pdf

Good afternoon Kevin,

Thank you for contacting Fluence Corporation and my sincere apologies for the delay in getting back to you, we are quite busy with inquiries at the moment. As requested, please find the attached technical information for the 100 HP floating TORNADO aerator. The budgetary price for one (1) 100HP TORNADO with 8-float system is $30,896. It is estimated to deliver 1.2-1.6 lbs of O2 per HP per hr.

Please refer to the attached technical specification for more details regarding TORNADO construction.

Feel free to reach out to me if you have any questions or need additional information from us.

Best regards,

Dina Palumbo
Product Sales Manager, USA

fluence

Value from Water

fluencecorp.com
Direct +1 763.746.9271
Main +1 800.879.3677
7135 Madison Avenue West
Minneapolis, MN 55427

ASX: FLC

800-548-1234

USABlueBook
Get the Best Treatment

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Part#: 49744

Weight: 339.0 lbs

Brand: Fluence (https://www.usabluebook.com/m-2148-fluence.aspx)

Tornado® Surface Aspirating Aerator (10hp, 230/460V, 3ph)

- Reduce odors and ice buildup
- Proven year-round performance in all weather conditions
- High oxygen transfer and basin mixing efficiencies

Price:
$9,981.00 USD/Each
Need Help? Call 800-548-1234

The TORNADO family of surface aerators delivers excellent oxygen transfer and high mixing efficiency to a wide range of treatment processes. Their rugged construction and efficient design maximize treatment performance while minimizing energy consumption.

TORNADO Aerators are ideal for wastewater treatment and supplemental aeration. They deliver all aeration and mixing below the water surface, eliminating odors from splashing or spraying. These self-contained systems don't require any pumps or accessories, saving you big on installation and operation costs. Angle adjustment allows optimization of horizontal mixing velocities, mixing depths and bubble hang time.

Units deliver dependable, economical performance in all weather conditions, thanks to their self-heating design. All stainless steel construction provides excellent corrosion and UV resistance, even in the toughest conditions. Large-diameter stationary draft tube with unrestricted air inlet provides maximum power using the least amount of energy. No harmful bacteria-filled aerosols—keeps the treatment process safe and secure.

Includes: stainless steel floats and a 230/460V 3-phase motor.

Note: Mooring cables/ropes and electrical cable are not included; source locally. Alternate voltages available for all models. Contact USABlueBook for more information.

Shipping: Ships motor freight.

RELATED SEARCHES

Aquatornado Surface Aspirating Aerator 3hp (/P-265158-Aquatornadoreg-Surface-Aspirating-Aerator-3hp.aspx)

Aquatornado Surface Aspirating Aerator 2hp (/P-265161-Aquatornadoreg-Surface-Aspirating-Aerator-2hp.aspx)

150 Ft Cord (/P-334040-Kascoreg-High-Performance-Fountain-Aeratorsbquo-5hpsbquo-240vsbquo-3phsbquo-150-Cord.as

200 Ft Cord (/P-334048-Kascoreg-Display-Aeratorsbquo-5hpsbquo-240vsbquo-3phsbquo-200-Cord.aspx)

RELATED CATEGORY

Pond Lagoon Aerators Aspirating (/C-753-Pondlagoon-Aerators-Aspirating.aspx)

Pond Lagoon Aerators Display (/C-755-Pondlagoon-Aerators-Display.aspx)

RELATED PRODUCTS

(/p-265225-kascoreg-high-performance-display-aerator-5hp-1ph-240v-100rsquo-cord.aspx)

(/p-265225-kascoreg-high-performance-display-aerator-5hp-1ph-240v-100rsquo-cord.aspx)

Kasco® High-Performance Display Aerator (5hp, 1ph, 240V, 100' (/p-265225-kascoreg-high-

More Details (/p-265225-kascoreg-high-performance-display-aerator-5hp-1ph-240v-100rsquo-cord.aspx)

(/p-265283-aquarian-quantum-floating-aerator-5hp-230v-3ph-94sa5023036.aspx)

(/p-265283-aquarian-quantum-floating-aerator-5hp-230v-3ph-94sa5023036.aspx)

Aquarian Quantum Floating Aerator (5hp, 230V, 3ph), 94SA5023036 (/p-265283-

More Details (/p-265283-aquarian-quantum-floating-aerator-5hp-230v-3ph-94sa5023036.aspx)

(/p-265285-aquarian-quantum-floating-aerator-75hp-230v-1ph-94sa7502301.aspx)

(/p-265285-aquarian-quantum-floating-aerator-75hp-230v-1ph-94sa7502301.aspx)

Aquarian Quantum Floating Aerator (7.5hp, 230V, 1ph), 94SA7502301 (/p-265285-

More Details (/p-265285-aquarian-quantum-floating-aerator-75hp-230v-1ph-94sa7502301.aspx)

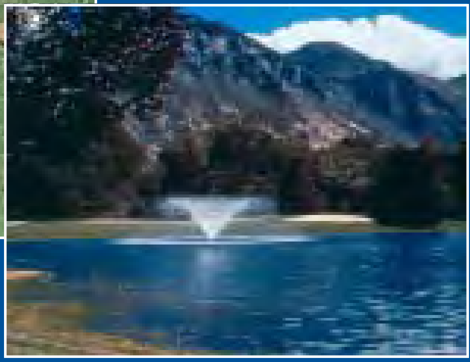
Appendix E - Oxygen Transfer Calculation Source

Filed under separate cover due to its size.

Appendix F - Otterbine Barebo Inc. Pond Management Guide

POND AND LAKE MANAGEMENT

Manual and Guide on Water Quality Management for Ponds and Lakes



Manual provided to you by Otterbine® Barebo, Inc.

Integrated Pond & Lake Management Manual & Guide

TABLE OF CONTENTS

DYNAMICS OF A LAKE

Water quality is a critical factor in the successful management of any golf course, turf, commercial or residential property. Poorly managed water will have a negative impact on the quality of the environment, turfgrass, irrigation system and the aesthetic value of the property.

Consider the negative impact of ingesting polluted water and air. These same principles hold true in the aquatic ecosystem and in managing our golf courses, landscapes and properties. Water is one of our most important and least understood natural resources.

Many of our ponds, lakes, irrigation basins, and water features are not well managed. We tend to treat the visible symptoms of poor water quality such as, algae blooms, aquatic vegetation growth, odors, clogged sprinklers, valves and pumps - rather than prevent them.

Our understanding has been superficial, leading to aspirin and band-aid type solutions that address acute problems and even appear to solve them temporarily but leave the underlying chronic causes untouched to fester and resurface time and time again.

Figure 1

A better understanding of the causes of these problems leads to long term, environmentally friendly, cause related solutions - which are preventative in nature.

Just as agronomists are the experts in turfgrass, ***limnologists*** are the experts in lake management. This material comes from a collection of research done by some of the world's leading limnologists located at The University of Florida and The University of Minnesota, both of which provides testing and research in the field of aeration systems oxygen transfer and circulation.

Otterbine's fifty years of practical experience in lake management is also a great source of knowledge. Our goal is to provide you with a comprehensive background of the state of the art in water quality management, as well as to create a paradigm shift.

Paradigm comes from the Greek word meaning "to design." Hopefully after reviewing this manual you will gain a better understanding of the causes of poor water quality and if necessary are able to 're-design' your approach to water quality management, allowing you to design an appropriate water quality management program that is preventative as opposed to fixative. After all you've probably heard the euphemism "An ounce of prevention is worth a pound of cure." This is especially true in regards to lake management.

"Every Lake is a Unique Ecosystem"

Imagine two lakes that are side by side, one is fresh, clean and healthy an asset to the property, while the other is dirty, weed-infested and creates odors (*Figure 1*). Why? Every lake is a unique ecosystem, and unfortunately there are no magical cures for lake problems. This is why it is essential for you to understand the causes of problems as well as the effects.

By increasing your understanding you'll be able to develop a balanced management and prevention programs for your lakes. As greens keepers or property management professionals you are well aware of our responsibilities and our ability to have significant positive impacts on the environment.

Next we'll be reviewing lake dynamics. This includes types of lakes, regions of the lake, and the importance of establishing and maintaining an ecological balance.

In order to design and put into practice preventative water quality management programs it is essential to have a firm understanding of the causes of water quality problems.

We'll review the effects of poor water quality and the related costs to the property owner or manager, as well as focusing on crafting cause-oriented solutions, designing programs to put your lakes in ecological balance and preventing nuisance problems in the future.

Knowing the type of lake you are managing will help you to establish a benchmark for the typical problems you might expect and the management programs you will be able to enact. As you review the three basic types of lakes, be sure to do a quick inventory on the lakes you manage. Which category do they fit in?

Lakes are generally classified into one of these three categories:

1. *Oligotrophic* (or new)
2. *Mesotrophic* (or middle aged)
3. *Eutrophic* (or old)

The age of the lake and the design of the lake are two critical factors we must consider.

Each lake has zones or regions and it is essential that the lake manager be aware of these zones and use them in maintaining an ecological balance in the lake. A lake that is in balance is a healthy lake, aging at a slow rate.

Oligotrophic lakes are clear, cold lakes with low nutrient levels and few macrophytes or plants. Geologically speaking, these are "new lakes." Oligotrophic or new lakes have very low levels of phosphorus, usually less than .001mg\l and there is little or no algae present.

Mesotrophic lakes tend to have intermediate levels of nutrients and macrophytes or plants and could be considered "middle aged lakes." These lakes have higher levels of phosphorus and experience some weed and algae problems.

Eutrophic lakes are characterized by high nutrient levels, turbid water, and large algae and macrophyte plant populations. Phosphorus levels can be in the range of 1mg\l. Considering that one gram of phosphorus will produce 100 grams of algal biomass, eutrophic lakes contain high algae populations.

Lakes evolve through a natural aging process. Under natural conditions this process takes hundreds, sometimes thousands of years.


Figure 2a

Cultural eutrophication, which is the acceleration of the aging process through human inputs, speeds up this aging process at an exponential rate. These human inputs include erosion, chemicals, fertilizers, waste runoff, leaky septic systems and more. The greater the level of the input the faster the lake or pond ages.

A great majority of the lakes we manage are man-made. Many times these lakes are poorly designed, may have artificial water tables, and most are so shallow that within a few short years they pass from oligotrophic (new stage) to eutrophic (old stage).

Excessive runoff accelerates the aging process of a lake exponentially. Special attention and management programs are necessary to overcome these effects of aging and keep the lake productive and aesthetically pleasing.

Were you able to identify which categories your lakes are in? This is one of the first steps in creating a management program custom fit for your application.

We can divide the lake into regions based on location within the water body. Both the shape of the basin, ***morphometry*** *(Figure 2a)*, and the shoreline characteristics, ***morphology*** *(Figure 2b)*, have significant importance to the lake manager.

Inside these lake regions there are zones which have tremendous influence over water quality and our approach to management. These zones include the ***littoral***, ***limnetic***, ***euphotic***, and ***benthic*** zones. Let's take a closer look at these regions.

Morphometry and morphology have significant influence over mixing in the basin. Both vertical and horizontal circulation are important in creating and maintaining a balanced ecosystem.

Morphometry, or lake shape, has tremendous influence over horizontal mixing. Long narrow channels or canals often experience water quality management problems. Isolated peninsulas can create physical barriers to mixing and, water quality issues can more easily occur.

Morphology, or the shoreline characteristics of a lake, has significant impact over vertical mixing and plant populations.

Different plants thrive at different depths.

For a more in-depth review of morphology we must begin by exploring specific shoreline characteristics.

First, the ***littoral zone*** *(Figure 2b)* is the region of the pond sloping from the shore out to the area of open water. It is the interface between the drainage basin and the open water, most generally the area where sunlight will penetrate to the bottom of the lake. The size of the littoral zone is dependent upon pond depth, clarity and

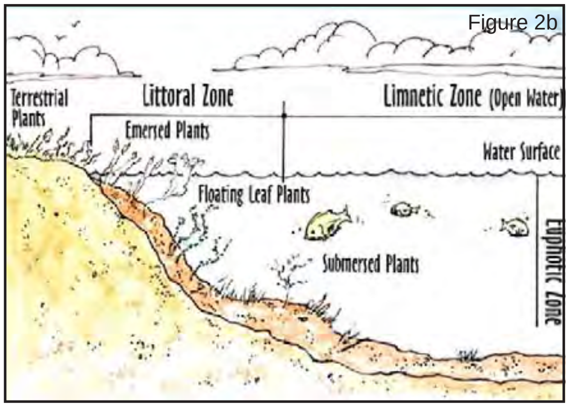


Figure 2b

wave action. Sunlight, wave action and the lake bottom have a great influence over this zone. Typically, this is the most challenging region of the lake to manage.

You will often see a ring of plants around the shoreline in the littoral zone. The variety and type of these plants are dependent upon depth. A variety of algae, including filamentous found in the littoral zone, will typically make up 90% of the species found in the lake. Algae in the littoral zone are often attached to macrophytes, which are emergent rooted aquatic plants such as rushes and reeds, and they thrive in this zone. Algae and macrophytes make excellent habitat for natural clean up tools like micro flora and zooplankton. Zooplankton are microscopic animals like protozoan, micro crustaceans, rotifers and larger invertebrates such as: aquatic worms, crayfish, insect larvae, and fish.

The second region of review is the ***limnetic zone***, or open water zone *(Figure 2b)*. This is the area in the lake that starts at the intersection of the littoral zone and extends out into open areas of the pond. Shore and bottom lake areas will tend to have less influence in this lake region. Planktonic algae, water lilies, submerged pondweed, zooplankton, invertebrates and fish are commonly found in the open water zone. This lake region is typically easier to manage.

The third region for review is the upper, well illuminated layer of the water - or ***epilimnion*** *(Figure 2c)*. This is the area where photosynthesis by algae and other aquatic plants occurs.

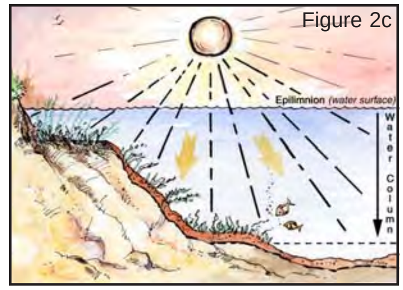


Figure 2c

The water column is the vertical column of water contained in the pond. This term is often used when discussing lake characteristics such as oxygen levels, temperature and nutrient content.

The fourth region for review is the ***euphotic zone*** or ***photozone*** area *(Figure 2d)*. This is the upper layer of the pond where sunlight can penetrate to promote the growth of green plants. We'll review the importance of light to the aquatic ecosystem in just a short while.

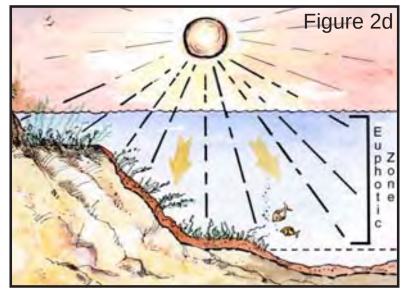


Figure 2d

Finally, the ***benthic zone*** is the area at the bottom of a pond or lake *(Figure 2e)*. The benthic zone is comprised of sediment and soil and usually has a high demand for dissolved oxygen.

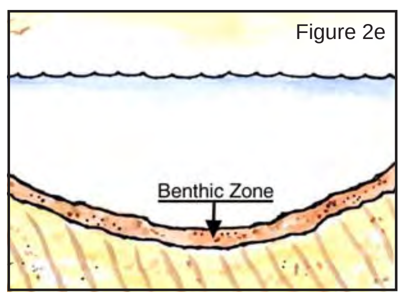
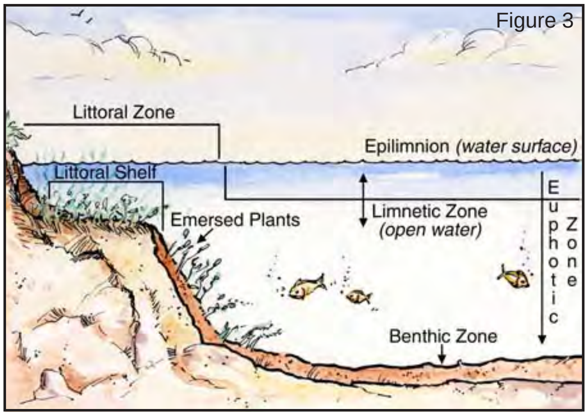


Figure 2e

Let's put it all together...

(Figure 3) The littoral zone is the shoreline area where nutrients will runoff into the water. The shallow nature of this zone and the fact that most nutrients will enter the basin through the littoral zone make it the most difficult area in the lake to manage. The limnetic or open water zone is deeper and easier to manage, while the euphotic zone is the region of the water column that is lit by the sun. Depending on turbidity, most of the lakes we encounter have euphotic zones that extend anywhere from 80% to 100% of the water column. And the benthic zone is the nutrient enriched, oxygen starved bottom layer of the lake.



A balanced lake management program will take all of these zones and regions into account and use each to help achieve ecological balance.

A lake in ecological balance is a healthy, dynamic ecosystem that is aging at a very slow rate where fish and other forms of aquatic wildlife are present, and there is an absence of foul odors and algae blooms. As nutrients enter the ecosystem they are either absorbed by the aquatic plants or metabolized by ***aerobic bacteria*****.** There are safe levels of oxygen present in all regions of the lake with a minimum of 4 PPM or mg\l. Oxygen is added to the lake from wave and wind action, the light side of the photosynthesis process, and rain. It's a healthy, balanced ecosystem. Mother Nature has provided the necessary clean up mechanisms to keep the lake in balance.

However, this balance is a delicate one. Typically there is an influx of nutrients, as aerobic bacteria respire and consume oxygen they will metabolize nutrients. This process keeps the available nutrients at a healthy level and everything is fine until a hot, humid, cloudy day occurs when the planktonic algae doesn't photosynthesize and create oxygen or the first long, hot night when oxygen demand soars.

In these scenarios there are no oxygen producers but there are many oxygen consumers, especially in stratified waters where all the demand for oxygen can't be met. We experience an oxygen stress and in turn a fish kill where the lake then turns ***anoxic*** or ***anaerobic***. The limiting factor is oxygen, while the fish kill isn't the first indicator that there is a problem it's usually the most dramatic and understandable one.

CAUSES OF WATER QUALITY PROBLEMS

As managers, it's important that we understand the factors that impact this delicate balance. The three most significant factors to the lake manager are:

1. *Light and Temperature*
2. *Nutrients*
3. *Oxygen*

Sunlight is of major significance to lake dynamics as it's the primary source of energy. Most of the energy that controls the metabolism of a lake comes directly from the solar energy utilized in photosynthesis. Photosynthesis will occur only in the euphotic zone *(Figure 3)* or upper layer of the pond, this is the area in the water column that sunlight is able to penetrate. Shallow bodies of water less than 9ft/3m in depth more commonly experience problems such as bottom-rooted weeds or benthic algae.

Thermal Stratification is a term meaning temperature layering. As the sun shines on a pond it warms the surface water, this water becomes lighter than the cooler, denser waters which are trapped at the pond's bottom. As the hot summer season progresses the difference in temperature between the warm surface waters and the colder bottom waters grows. As a result the water becomes stratified or separated into layers with the top and bottom layers of the lake do not mix with each other. The area between the warm and cold layers, called the ***thermocline*** or ***metalimnion*** *(Figure 4)*, can act as a physical barrier preventing any vertical mixing in the lake. And, remember warm surface waters encourage algae growth.

Have you ever experienced this phenomenon when diving into a pool or lake and noticed that the water is colder at the bottom than on the surface?

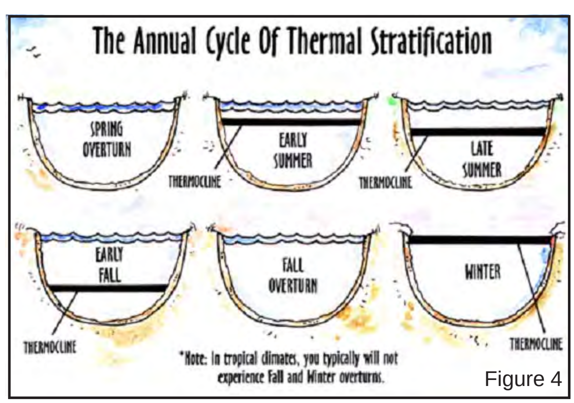


Figure 4

Thermal stratification impacts the water quality in a lake primarily because of its effect on dissolved oxygen levels, the way we measure how water holds oxygen *(Figure 5)*. Warm water has a diminished capacity to hold oxygen, in fact water at 52 degrees Fahrenheit or 11 degrees Celsius can hold over 40% more oxygen than water at 80 degrees Fahrenheit or 27 degrees Celsius. *As water temperature increases, the water's capacity to hold oxygen decreases.*

Dissolved oxygen in a lake comes primarily from photosynthesis and wave/wind action. During stratification, bottom waters are removed from both of these sources and an anoxic or no oxygen condition occurs. Aquatic organisms require oxygen to survive, in its absence organisms must move from the anoxic area or die. Anoxic bottom waters lose most if not all of the zooplankton and aerobic bacteria necessary for efficient and effective digestion, while less effective more pollutant tolerant forms of anaerobic bacteria will develop.

Thermal Stratification Effects on Dissolved Oxygen

Degrees Celcius	Degrees Fahrenheit	Oxygen Saturation
11°C	52°F	11 PPM
17°C	62°F	10 PPM
22°C	72°F	9 PPM
27°C	80°F	8 PPM

Figure 5

The lack of dissolved oxygen sets in motion a series of chemical reactions that further reduce water quality: sulfide is converted to hydrogen sulfide, insoluble iron is converted to soluble forms, suspended solids increase and a severe decrease in the decomposition of waste materials on the pond bottom will occurs.

Thermal stratification occurs in a seasonal cycle with the thermocline becoming more severe in late summer and late winter. Lakes and ponds in warmer weather regions experience a shorter annual cycle spending more time in late Summer and early Fall conditions.

Shallow lakes offer the water manager an even greater challenge. Shallow ponds less than 6ft/2m in depth tend to be very warm allowing for the entire water column to be productive with weed and algae growth. These types of lakes need extra consideration when determining the correct water management solution.

The second essential factor in our lake management discussion is the impact of nutrients on the aquatic ecosystem. There is a direct correlation in the level of available nutrients and the populations of algae and aquatic weeds.

To gain a deeper knowledge it is important to understand the sources of nutrients, how the nutrients are absorbed and broken down, and the impact nutrients can have on water chemistry. In fact a diagnosis of a lake's chemical make up can help you design a preventative program for a problem lake.

We need to consider the way that organic nutrients are accumulated and digested in the lake. An organic nutrient is a carbon based compound essential to the life of a plant. In lake ecology the macro nutrients we specifically talk of are phosphorus and nitrogen. In fact, phosphorus has been identified as the single greatest contributor to aquatic plant growth, remember that one gram of phosphorous will produce one hundred grams of algal biomass. As the nutrient level in the water increases so does aquatic plant and weed growth, this leads to severe problems from an environmental and aesthetic viewpoint.

It is beneficial to try to identify the sources of nutrient coming into the pond. The three most common sources are bottom silt and dead vegetation in the lake, runoff water from surrounding turf areas, and the sources of incoming water.

Vegetative life in the lake and sediment at the lake bottom are the primary sources of nutrient. Although they only have a two-week life cycle, blue-green algae can experience cell division and double their population as often as every 20 minutes. At the end of the cycle, the plants simply die and begin to sink to the lake's bottom, adding to the biomass, or total amount of biological material in the pond *(Figure 6)*. This adds to the "aquatic compost pile" at the benthic zone or bottom. The layer of dead plant material acts as nutrient for future algae and aquatic weed blooms, a phenomena called ***nutrient cycling***. Nutrient cycling creates additional demands on the

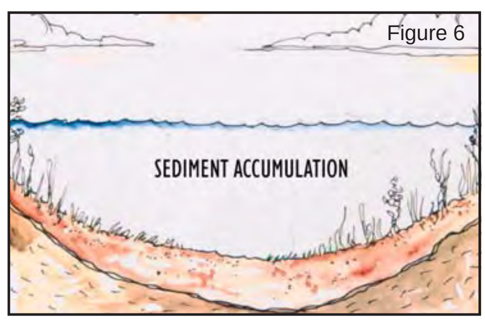


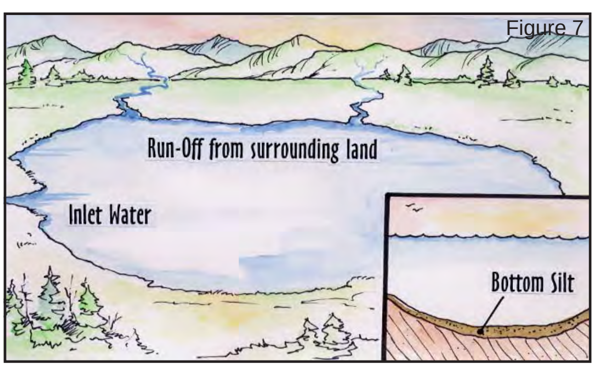
Figure 6

available oxygen in the hypolimnion, or bottom, and creates a stress situation.

Studies at the University of Florida indicate that sediment or *sludge build up can accumulate at a rate of 1 to 5 inches or 2.5 to 12cm per year* in temperate climates. While in tropical climates the rate increases to 3 to 8 inches, or 6 to 16 cm per year all depending on the level of nutrient loading.

At a mid point accumulation rate of 3 inches or 7cm per year, a one surface acre or a 4000 square meter lake will lose 80,000 gallons or 300 cubic meters of water storage capacity in a single year. Imagine the impact on an irrigation storage basin over the course of ten, twenty or fifty years. Sludge build up can gradually occur, robbing any lake or irrigation basin of it's capacity to store water.

The second most common source of nutrients is runoff from surrounding turf areas as well as roads, farms and other outlying areas *(Figure 7)*. The USGA reports that up to 4% of the fertilizers applied to areas adjacent to ponds and lakes may eventually runoff into the lakes, this runoff of fertilizers into lakes is known as ***nutrient loading***. Consider that a golf course may apply up to sixteen tons of fertilizer in a year the possibility for a half ton of fertilizer to runoff into the lakes or drainage basins exists. Leaves, grass clippings, and other materials will also runoff into the lakes, placing additional burdens on the lake's natural clean up processes. Ponds and lakes often act as Mother Nature's "garbage cans."



Nutrient loading can be very high in waters adjacent to green areas or turf grass. As the nutrient levels in the pond increase, the rate of plant growth will increase as well. The following chart shows the impact that nutrient levels can have on aquatic plants and algae.

A case study presented by the North American Lake Management Society (NALMS) suggests that the algae can absorb over 1mg\L of phosphorus and over 2.5mg\L of nitrogen *(Figure 8)*. Nutrients do have a significant impact on algae and aquatic weed growth, increased nutrient levels usually mean increased plant levels.

Nutrient is also added to our lakes and ponds through inlet waters. This inlet water can come from effluent sewage, wastewater treatment plants and leeching from septic systems. Often inlet waters have minimal oxygen and are loaded with phosphorus, an indication of excess phosphorus is foaming water.

Nutrient Loading: NALMS Case Study

	Total Nitrogen	Total Phosphorus	Algae/ Weed
Incoming	3.22 mg\l	1.7 mg\l	< 1%
Water at Lake Center	.50 mg\l	.62 mg\l	> 40% Algae Covered

Figure 8

The third essential factor in lake and pond ecology is the role oxygen plays. Oxygen is important to all forms of life in the lake, after all how long can we live without air? Oxygen supports the food chain in a lake or pond, a healthy ecosystem in a lake contains a wide variety of plants and animals including a natural mechanism to biodegrade organic nutrients. The bottom of the food chain consists of microscopic algae which are consumed by slightly larger zooplankton. Each level of consumer transfers a small fraction of the energy the lake receives up the food chain to the next level of consumer. This means that a few sport fish depend on a much larger supply of smaller fish, and in turn the smaller fish depend on a large base of plants and algae. This large mass of plants and algae require an even larger amount of nutrient to grow, a healthy food chain can pull a tremendous amount of nutrient out of the water. Oxygen supports this entire system.

Natural decomposition processes in the aquatic ecosystem are oxygen dependent. Aerobic digestion is a fast and efficient way of breaking down nutrients. Moreover, an abundant supply of dissolved oxygen supports the oxidation and other chemical processes that help keep the lake in ecological balance.

How is a lake supplied with oxygen? From several sources but primarily through photosynthesis, wave and wind action. Aquatic plants and algae produce large amounts of oxygen through the light process of photosynthesis. This is an important source of oxygen in most lakes especially older, eutrophic lakes. At night plants become oxygen consumers in the dark process of photosynthesis and produce carbon dioxide. The other significant oxygen producer is the oxygen transfer created by wave and wind action. The surface area of the lake is increased by surface waves or ripples caused by wind or other means, this wave action created by the wind creates additional circulation and partially breaks down thermal stratification. Surface waters that have direct contact with the air will be oxygenated through diffusion. And finally, as the rain passes through the atmosphere it picks up free oxygen and deposits it in a dissolved state when it strikes the surface waters of the lake.

Oxygen depletion or stress situations occur for different reasons. Whenever oxygen levels fall below 3 to 4 PPM or mg\L an oxygen stress will occur. Typical situations when this will happen are:

- Late at night and just before dawn
- Cloudy and still days
- Hot and humid days
- When the lakes nutrient content is high
- After a chemical application

The most immediate reactions to oxygen depletion would be fish kills or odors. Long term issues include nutrient build up, sludge accumulation, and a chemical imbalance in the lake.

Nature has provided a clean up process that will metabolize or decompose excess nutrients. This process is called ***organic digestion***. Two types of naturally occurring bacteria are present in all lakes and ponds, ***aerobic*** and ***anaerobic***. The bacteria in the water will work to break down the nutrient load by feeding on the organic nutrients and digesting it into non-organic compounds that algae and aquatic plants can not readily use for food.

The most effective of these bacteria are ***aerobic bacteria***. Aerobic bacteria only live in the presence of oxygen and they metabolize or break down nutrients respiring or consuming oxygen in the process. They are very efficient, breaking down organic nutrients, carbon dioxide and other materials and are roughly seven times faster in organic digestion than anaerobic bacteria.

Anaerobic bacteria also break down organic nutrient and exists in pond water and soils that are oxygen deficient. They are not as effective as aerobic bacteria in the digestion of organic wastes and allow soluble organic nutrients to re-cycle into the water column. Noxious by-products such as methane, ammonia and hydrogen sulfide are created by anaerobic decomposition. In general, any foul smelling waters can be assumed to be anoxic or oxygen deficient.

Oxidation is a chemical process that is dependent on oxygen. Oxygen has a positive molecular charge, as an oxygen molecule affixes itself to a particle in the water it then starts to oxidize or break down the molecular bonds which hold the particle together. In addition, the positive molecular charge of the oxygen molecule will create an attraction and pull several small particles together, a process known as ***coagulation***. These heavier, coagulated particles now precipitate, or fall out of suspension. In this process soluble substances like phosphorus and iron become insoluble and unavailable for use by aquatic vegetation. A balanced aquatic ecosystem contains a fairly low population of algae and aquatic weeds as well as other forms of nutrient. Aerobic bacteria feed on the organic nutrients and digest it into non-organic compounds that algae and aquatic plants can not use as readily for food.

Simple water quality tests will indicate the nutrient levels and other valuable information in regards to lakes and ponds *(Figure 9)*. These tests typically monitor dissolved oxygen, biological oxygen demand, alkalinity, pH, phosphorus, nitrogen, and fecal coliform in some situations. Dissolved oxygen is described in either parts per million or milligrams per liter. Biological Oxygen Demand is referred to as BOD. The chart indicates the appropriate levels for lakes and ponds. This testing can be completed by most water testing laboratories and water testing is important for a complete understanding of the water you are trying to manage.

Let's put it all together...

Let's take a look at how all of these mechanisms interact to make the lake behave the way it does. As a lake ages the level of nutrient rises, this is due to an increase in runoff, organic bottom sediment, or fertilizer used in the surrounding area, and in the amount of algae and aquatic weed growth. As these weeds grow and die they sink to the bottom of the pond to decompose, this will result in a sudden increase in the activity and population of aerobic bacteria due to the large food supply. The depth of the lake will decrease as the biomass at the lake bottom accumulates. Aerobic bacteria will use a large amount of oxygen as they digest organic waste, with primary source of oxygen in the pond coming through surface contact, rainfall and plant photosynthesis.

WATER QUALITY TESTS: APPROPRIATE LEVELS

Dissolved Oxygen	>4 mg/l *(check before sunrise)*
BOD	<5 mg\l
pH	6 to 9 *(7-8 are neutral)*
Alkalinity	>50 mg\l *(well buffered)*
Chlorophyll	<2 mg\l
Suspended Solids	<5 mg\l
Fecal Coliform	<200 per 100 ml *(no human contact if >400)*
Total Nitrogen	<5 mg\l
Total Phosphorus	>.05 mg\l *(considered high)* <.1 mg\l *(will experience algae blooms)*

Figure 9

Due to thermal stratification the top and bottom layers of the pond will not mix and the needed oxygen can not get down to the lake bottom to support aerobic digestion. This will cause an oxygen depletion problem in the lower layers of the lake and may result in nutrient cycling, fish kills and foul odors caused by anaerobic digestion. The problem is caused by poor water quality, that is excessive nutrient levels, poor circulation and low oxygen levels.

Balance is critical to the aquatic ecosystem. A healthy lake contains balanced amounts of oxygen, nutrients, and temperature.

RESULTS OF POOR WATER QUALITY

Now that we have a deeper understanding of the actual causes of water quality problems, let's identify the effects or symptoms. This includes algae, weeds and odors. Associated with these effects are the costs of fixative programs. It is important that you understand the high cost of not acting, once a lake has lost its ecological balance and goes into crisis the costs of restoring the lake increase dramatically.

Many people view algae as the lake management problem but the true problem is poor water quality, a lake that is out of ecological balance. Algae and aquatic weeds are some of the first visual indications of poor water quality. Algae is better viewed as a symptom, blooms of microscopic and filamentous algae can be unsightly and can disrupt full enjoyment of the lake or pond. Planktonic algae are single or multiple cell plants found near the surface or epilimnion, they often are a light green in color and can create a "pea-soup" appearance to your lake. A lake with an abundance of Planktonic algae runs the risk of causing an oxygen depletion or stress emergency. Often during a cloudy, hot, summer day or late at night these algae can consume all the available oxygen in the water. When this happens we will see a fish kill or a mass algae die-off. An algae die-off can occur for a variety of reasons, a cold snap, lack of light, or a chemical application. The lake will change from a light green to a brown color overnight. The dead algae will produce additional demands on the available oxygen creating a negative visual aspect and odors to the environment.

Benthic or filamentous algae is a very difficult type of algae to control. These plants grow from the bottom of the lake or benthic zone, break loose and float to the surface. They will only grow in conditions where the depth and turbidity of the water allow sunlight to reach the lake bottom. These algae are often called moss or cotton algae, some species have small air bladders that float the algae to the surface. Once at the surface, this algae becomes an ideal habitat for mosquitoes and other insects.

Probably the most difficult type of weed to eradicate are bottom rooted vascular plants. These plants often have small air sacks or bladders attached permitting them to float and to keep them in suspension. Bottom rooted, vascular weeds will only grow where the sunlight penetrates to the pond bottom. All of these weeds and algae have one common benefit... they help reduce the available nutrients in the lake.

What are the impacts that algae and aquatic weeds create for the lake or property manager?

- Increased nutrient/biomass levels in water causing sludge build-up

- Oxygen depletion issues such as odors and fish kills

For the property manager the negative effects and costs of poor water quality are very real and can impact the property both in aesthetic and functional ways. Clogged irrigation valves can create havoc on the turf while sediment build-up reduces storage capacity in water basins and aesthetic appeal is lost through odors, fish kills and algae.

If a vertical turbine pump becomes fouled it will be necessary to bring a diver to the site. Commercial divers are usually not immediately available nor are they always conveniently located, this may lead to delayed repairs due to logistical concerns during which the turfgrass receives no irrigation. Once the diver arrives at the site, the pump intakes can be cleared in four to eight hours. Costs to the manager are in the $500 to $1000 range and this cost does not include travel time or damage done to the turf.

If a valve or sprinkler fouls, the problem is smaller in scope but still serious. It may take several days to identify that a sprinkler or valve is clogged. In the interim the turfgrass can either burn out due to lack of water or become saturated with excess water *(Figure 10)*. This repair is fairly simple and it normally takes two to four hours, however it can be especially difficult on a golf course where ground under repair can interfere with normal play. The costs to fix a valve or sprinkler ranges from $120 and upward.

Remember sediment increases the lake's oxygen demand and makes additional nutrients available for aquatic plant growth. Under certain conditions it is possible for the sediments to pass through the irrigation system out onto the turfgrass, this can happen when rain or wind mixes sediment back up into suspension. The intake for the irrigation pumping system's intake is near the bottom of the lake where the sediments can block pumps, pipes, valves, and sprinklers. Costs can become excessive, for instance at El Dorado CC in Texas costs of $7,500 per year were incurred to repair damage to the pumps, while at Great Hills Golf Course in Texas annual costs exceeding $20,000 per year are spent to clear blocked pipes, valves, and sprinklers.


Figure 10

If the pumping system passes the sediment out onto the turfgrass or golf course a new set of problems arise. The sediment at the bottom of the lake will often contain heavy metals, anaerobic bacteria, and partially decomposed organic material

When this sediment is applied to the turfgrass it can create a "***black layer***" in the grass root zone. This layer will effectively seal the turf and not allow oxygen, water, or nutrients to percolate down to the roots of the turfgrass, creating disease or even death of the grass.

Should this happen, it will be necessary to replace the greens or core out and install new USGA mix in the turf. The costs here can be staggering. Coring out and installing new USGA mix costs $10,000 to $15,000 per green. The cost to rebuild and reshape a green can range from $35,000 to $45,000 per green or a possible total cost of $850,000. Mr. Jim Moore, Director of Education for the USGA states, "This is a lot bigger problem than most people realized. It's destroyed a lot of greens, clubs are faced with the reconstruction of greens and tees built within the last ten years because of lousy water quality."

Sludge build up (eutrophication) as stated earlier impacts the manager in different ways. With the reduction in the basin's capability to store water, it has severe impact if the lake is an irrigation storage basin or a storm water retention pond. In either instance, the lake has been designed to hold a given capacity of water which have now been diminished *(Figures 11a & 11b)*.

Oxygen depletion can lead to fish kills and odors. Warm water fish require roughly 4 PPM (parts per million) of dissolved oxygen and cold-water fish require 5 PPM of dissolved oxygen. As

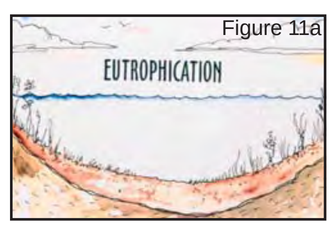


Figure 11a

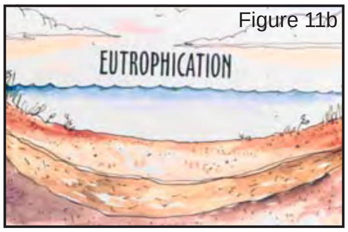


Figure 11b

mentioned before when oxygen levels in a pond drop one of the first indicators is a fish kill. When fish go into an oxygen stress you will typically see them at the surface where a minimal oxygen transfer occurs through oxygen diffusion.

Odor problems in ponds are generally traced to four causes:

1. *Algae*
2. *Chemical pollution*
3. *Geological conditions*
4. *Low oxygen levels resulting in an anaerobic condition*

By increasing oxygen levels and circulating oxygen rich water throughout the pond, anaerobic conditions can be minimized while odorous gases can be stripped out of the water. These conditions are generally treatable through filtering or aeration.

Therefore, problems associated with poor water quality such as: excessive weed and algae growth, clogged sprinkler heads, valves and pumps, sludge build up and reduction of storage capacity, black layers under turf, as well as unpleasant odors, diminished aesthetics and insect problems are avoidable if the lake manager puts a proactive, preventative lake management program into place.

PREVENTATIVE PRACTICES

The lake manager has many water quality management tools available. The art of lake management lies in the design of an integrated lake management program properly aligning the best solution with the chronic causes of quality issues. The manager should strive to create an environmentally friendly program which is preventative in nature. Proactive management means preventative management, keeping the lake in ecological balance by design. Reactive management typically means crisis management, where the lake manager waits until the lake is thrown out of ecological balance and a crisis occurs. Reactive solutions tend to be less friendly to the environment and more costly to implement.

In order to identify the proper preventative practice it is important to identify the true causes of the problem. How does the problem relate to the three factors that have the most impact on water quality management: sun light and temperature, nutrients and oxygen? With the growing awareness of the importance of water quality and its impact on the environment, preventative practices revolve around these issues and offer the most acceptable solutions as these solutions are directed at the causes.

Many lake management issues are related to light and the heat generated by the sun. Shallow lakes with a severe benthic or filamentous algae problem would be in this category. To attack the causes of excess solar radiation we need to look at the basin configuration and the use of lake dyes to block U.V. penetration.

Proper lake design or configuration is the first step towards sound water quality and will minimize many of the inevitable management issues that arise as the lake ages. Many of the lakes we encounter are man-made, so when designing a lake it is critical that the designer keep the biological factors in mind as morphometry and morphology play important roles in the dynamics of the lake. Unfortunately there are many times lakes are designed too shallow, creating unnecessary problems that could have easily been avoided in the initial stages of development. Proper lake design is the first step towards sound water quality and will minimize many of the inevitable management issues that arise as the lake ages.

In regards to the shape of the lake (morphometry) long isolated peninsulas or fingers of land that interfere with circulation should be avoided. The shoreline of the lake (morphology) should allow for a littoral shelf where nutrients can be buffered or absorbed by plants before reaching the limnetic zone (*Figure 12a & 12b*). A minimum of 9ft/3m is suggested for the depth of the basin. This depth will allow for sunlight and provide an area that should not experience bottom rooted plants and have cooler waters to mix with surface waters. ***Shallow, warm ponds can be the lake manager's greatest challenge***. By allowing for reasonable depths it will help minimize the impact of solar radiation and the related heat on the lake.


Figure 12a

There are also a lot of times the lake or water feature is constructed as an artificial water table in a place where a lake or pond would not occur naturally. In many cases the soil on the site is not suitable to hold water, while in some areas environmental concerns dictate that drainage water from the site does not make contact with underground water tables. All of these factors have resulted in the greater use of lake-liners (*Figure 13*).

Figure 12b

When using a lake-liner, subgrade preparation is an important factor to a successful project. The site manager should take groundwater into account and if present they should develop a french drain system that will allow water to flow laterally under the lining depositing the drainage water in a gravel sump. This under drain will prevent the liner from floating due to ground water or gas build up under the liner. The lakebed should be well prepared before the liner is laid down making sure that it is smooth and well manicured to insure an easy and successful installation. Lake-liners can be a tremendous asset to the property manager.

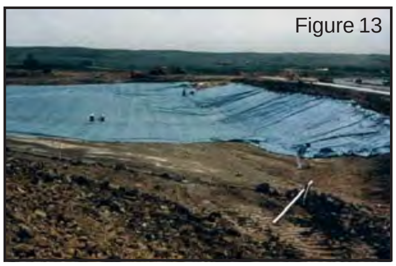


Figure 13

While there are different types of materials available PVC remains the most commonly specified choice. As UV rays will degrade PVC it is necessary to place a minimum of 1ft/30cm of topsoil over the liner once installed. Another material, reinforced polypropylene, is not affected by light and can be successfully installed without the use of topsoil to cover the liner. Traditionally clay or bentonite have been used as a liners, however they tend to crack and are not as widely used as they were once before.

Lastly, it is highly recommended that a provision for electrical supply be made to each and every lake. This is very inexpensive in the construction phases of the project and makes provision for supplemental aeration systems or other electrical needs later on down the road.

Lake dyes are an important proactive management tool for use in shallow lakes. These products can help offset the lack of depth by reducing the UV energy absorbed by the lake. A lake dye is a photosynthesis inhibitor, it blocks the penetration of sunlight into the lake, thus slowing the growth of aquatic plants. Lake dyes will also improve the appearance of lakes by masking or covering improving clarity or color problems.

Lake dyes are available in liquid or powder form and contain an inert form of powder similar to blue food colorant #5, be sure to choose a dye that is government or EPA approved. Use the dye in lakes or ponds that have no outlets or streams and it can help give your lake additional aesthetic appeal by enhancing the coloring of the water to a deep blue (*Figure 14*). Most lake dye will last an average of 6-8 weeks and will not harm fish or stain waterfowl.
Nutrient sources include inorganic and organic matter already existing in the lake, nutrients which runoff or leach into the lake, and the source of the water itself. The manager has a great degree of control over the nutrients that may runoff into the lake. Our goal should be to prevent as much nutrient as possible from reaching the water.

How can we best achieve this? One of the simplest ways lies in fertilization and mowing practices. You can create a "no fertilizer" zone in the immediate perimeter of any lake, we recommend a band of 30 feet or 10 meters if possible, this will help eliminate chemical runoff to enter the pond or lake. The use of slow release fertilizers will also help minimize fertilizer run off, as well as letting the turf grass grow longer in the turf grass-lake interface zone. Finally, a slight geological relief such as a swale or berm will help prevent organic nutrients and fertilizers from running directly into the water.

Figure 14

Another preventative, biological control method is the introduction of wetlands at the areas where water or runoff flows into the lake. The wetland area can perform two functions: slow the progress of water into the lake, reducing erosion and flooding problems, and secondly the intensive plant growth in a wetland area acts as a nutrient sink for the nutrient enriched waters flowing into the basin. The plants in the wetland will actually absorb nutrient before it has a chance to enter the lake. This can result in higher water quality due to lower organic nutrient levels.

A very effective form of biological control is using vascular, rooted plants as a buffer. This technique was pioneered over a decade ago by Dr. Bob Blackburn from Auburn University. He believes this technique to be the lake manager's "first line of defense." By planting these plants in the littoral zone they absorb the nutrients before they reach the water, helping to lower the nutrients available for algae, aquatic weeds, and bacteria.

The following chart (*Figure 15*) indicates which plants are suitable for different depths. We recommend that the seedlings or roots be planted 1ft/25cm apart.

Note: The choice of plants is related to depth, contact your local Department of Natural Resources or Conservation for more details on these plants. The scientific name may be useful in sourcing the less common plants. Like the wetland plants, these species will provide a wonderful habitat for fish and waterfowl as well as provide beautiful foliage.

Aquascaping: Suggested Plantings

Depth	Plant Types
0-1 ft 0-25 cm	Burred, Three Square Rush, Smartweed, Cattails
0-1.5 ft 0-40 cm	Wild Rice, Arrowhead, Bulrush, Pickerel
0-2 ft 0-50 cm	Deep Water Arrowhead, Water Lilies
1-5 ft 25-125 cm	Sago Pondweed, Water Celery

Figure 15

FOUNTAINS AND AERATORS

There is a significant difference between fountains and aerators. The primary function of an aerator is to add oxygen and induce circulation in the water. The primary function of a fountain is to create an aesthetic effect. For aeration purposes look for Oxygen Transfer Rates (OTR) in excess of 1lb/5kg per horse power per hour and pumps in excess of 300 GPM or 1200 LP per horsepower. Depending on site conditions we recommend 1HP to 3HP aerating units per surface acre or 4000 square meters.

Aeration, by definition, is the addition of oxygen into the water, the second component of aeration is circulation and destratification. Aeration is a scientific discipline first used to treat wastewater during the industrial revolution and continues to play an important role in the treatment of industrial and domestic waste. Aeration can also make significant improvements to effluent waters that are being used for turf irrigation, similar to creating a mini-treatment plant in your lake. Aeration is a holistic, preventative tool that will prolong the useful life of a lake.

How does an aerator improve water quality and control algae growth?

By impacting the three factors; oxygen, nutrients, and temperature. By putting large amounts of oxygen into the water, an aerator encourages a strong colony of aerobic bacteria which, in turn, works to clean the lake of organic nutrients and waste. Lastly, a properly sized aeration system will create circulation breaking down thermal stratification and lowering surface temperatures while adding dissolved oxygen to the lower regions of the lake (*Figure 16*).

The introduction of dissolved oxygen to the lake's bottom will inhibit phosphorus to release from sediments, curtailing this internal nutrient source. In fact, by adding oxygen to the lower levels of the lake a chemical reaction occurs which converts soluble forms of phosphorus and iron into non-soluble forms that can not be used by plants.

In addition to the problems related to growing turf grass in high iron conditions, iron in irrigation waters can cause staining of cart paths and buildings. The Water

Figure 16

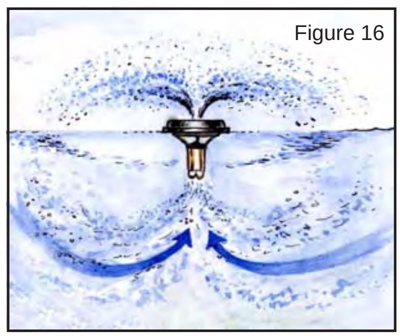


Figure 17

Pollution Control Federation tells us that iron staining starts at .3 PPM or mg\l.

An aeration system, if properly sized, can lower iron concentrations to .1 PPM or mg\l. At a case study in Western Australia, iron levels in the irrigation lakes were wreaking havoc on the turf grass (*Figure 17*). After proper aeration and minimal recon-figuration of the basin's design iron was reduced over 15mg\l from 17 PPM to .02 PPM (mg\l).

Scientific evidence indicates that aeration can help soften hard water and even lower high pH levels. This is due in part to mixing carbon dioxide enriched waters from the lake bottom up into the water column.

The high pumping rate or circulation rate of an aerator breaks down thermal stratification, mixing denser bottom waters with warmer surface water, distributing oxygen to all parts of the lake. By pulling cool bottom water up to the surface, the surface layers are cooled and the growth of algae is slowed. Single cell algae are mixed to the lake bottom increasing the cells time in darkness and slowing growth and reproduction. As you can see aeration effectively deals with the three factors of poor water quality: temperature, nutrients and oxygen keeping them all in balance.

By improving water quality we lower aquatic weed and algae growth, bottom sludge build up, odors, and insect infestation. In turn this has a positive impact on the irrigation and pumping system efficiencies, the environment, and aesthetics. Aeration attacks the source of the problem, poor water quality, and is an economical and on-going method of lake management. It has no harmful side effects and supports the natural ecosystem. By addressing the causes of poor water quality it is preventative and proactive in nature, an old saying goes, "An ounce of prevention is worth a pond of cure," nothing could be more true in the water quality management field.

AERATOR SELECTION

There are three basic types of pond aerators: Surface Spray, Horizontal Aspirators, and Air Diffusion Systems.

Each type is best suited for specific applications. The different types can be used in conjunction to treat several different types of problems in the same lake or on their own, depending on the situation.

Surface Spray Aerators provide the best vertical circulation in lakes less than 15ft or 5m deep, while Horizontal Aspirators are the choice for lakes between 3ft/1m and 12ft/4m deep that will benefit from a strong directional flow. Air Diffusion Systems are the most unobtrusive aerators and are most effective in water that is 15ft or 5m deep or deeper.

Figure 18a

Let's take a closer look at each system and their respective strengths.

Surface Spray (*Figure 18a*) type aerators provide the best vertical circulation in lakes less than 15ft or 5m deep. They lift bottom water up to the top and spread it out over the surface waters to aerate it and create convection currents. While they provide an attractive display, independent research indicates that these systems add 2mg per liter of dissolved oxygen at 10ft/3m in depth. The wave action caused by the spray pattern is excellent at breaking up algae mats and discouraging mosquito breeding.

Figure 18b

Horizontal Aspirators (*Figure 18b*) are the choice for lakes between 3ft/1m and 12ft/4m deep that will benefit from a strong directional flow. A good choice for applications where a spray pattern is not wanted or desired, these units are used to create artificial currents in long narrow ponds or canals and will also break up algae mats in stagnant waters.

Air Diffusion Systems (*Figure 18c*) are the most unobtrusive aerators. They are most effective in water that is 15ft/5m deep or deeper but can work in waters as shallow as four feet (*Figure 19a*). As the air bubbles will rise to the surface at 1ft/30cm per second, the system's efficiency is directly related to depth. At 9ft/3m in depth these systems operate at roughly 25% efficiency. As you can see the depth must be sufficient to allow for the rising air bubbles to entrain water towards the surface providing circulation and to transfer into the water column providing aeration.


Figure 18c

The way the system works is that a shore mounted air compressor forces a large volume of air through a supply hose to the diffuser located at the bottom of the pond. The diffuser emits the air in the form of thousands of small bubbles that capture or entrain the bottom water and carry it to the surface. Air diffusion systems have no surface presence other than a boil of bubbles which creates surface water movement that breaks up algae mats and discourages insect breeding, at the same time it provides excellent bottom to top mixing breaking up the thermacline. Air diffusion systems are economical to operate and can be used in conjunction with other types of aerators.

Air Diffuser Efficiency at Depth

Depth	Oxygen Transfer Rate per HP/Hr	Efficiency
15ft or 5m	4.4 lb or 2 kg	100%
12ft or 4m	2.2 lb or 1 kg	50%
9ft or 3m	1.1 lb or .5 kg	25%
6ft or 2m	.5 lb or .25 kg	12%
3ft or 1m	.25 lb or .12 kg	6%

Figure 19a

Be careful to choose the proper type of diffusers. Research indicates that the bubble size and density will effect oxygen transfer rates (OTR) and circulation rates. The following chart shows the efficiency of various systems at 6ft/2m in depth (*Figure 19b*). The test clearly shows that the aeration tubing is 24% less efficient than the synergistic air lift.

Diffuser Efficiencies at 6 Ft (2m)

Type of System	OTR per HP/Hr	Percent Differ-ence
Ceramic Diffusers (6 Diffusers in a 2' x 2' or 50cm x 50cm grid)	.4868 lb	--
Aeration Tubing (72in or 22m)	.37 lb	-24%
Flexible Membrane Diffusers	.2843 lb	-43%

Figure 19b

While waterfalls offer some aeration benefit they are not an effective replacement for an aeration system (*Figure 20*). The average waterfall will use a 5 HP to 25 HP pump to move roughly 1000 GPM or 3700 LPM over a 10ft/3m wall. This approach does not have appropriate oxygen transfer rates or the necessary circulation capabilities for true water quality management.


Figure 20

In order to be effective an aerator must have a very high pumping rate. As mentioned previously, look for a unit that pumps or moves at least 300 gallons per minute or 1.5m^3\minute per horsepower. Aerators are rated by their oxygen transfer rate, a good spray type or aspirating aerator will put 2 to 3 pounds or 1 to 1.3 kilos of oxygen into the water each hour for each horsepower, while an air diffusion system will do slightly more or less depending on the depth of the pond. Try to look for an aerator that has had independent oxygen transfer testing, the measurement with the most importance is S.A.E. or *Standard Aeration Efficiency*. This is the method approved by the American Society of Civil Engineers and rates the oxygen transfer by actual horsepower created.

Safety testing is very important, as most aerators are electrical appliances operating in water. Look for system-wide testing and approval by CE, C.S.A., ETL, or UL. Testing of individual components of a system without system-wide testing does not guarantee that the unit is assembled safely or that all of the components are properly sized or suited for your application.

Proper sizing and placement is the key to a successful installation, the best equipment will not be effective if it is used inappropriately (*Figure 21*). For Surface Spray and Aspirator units you will want to use 2 horsepower per surface acre or 4,000 square meters of water. Add more horsepower if the lake is less than 6ft/2m in depth, if there is evidence of high nutrient levels or if it is an older lake with a heavy organic sludge layer. Air Diffusion systems use approximately one diffuser for each 1.5 acres or 6,000 square meters of water assuming the depth is at least 15ft/5m. In shallower lakes significantly more diffusers will be required.


Figure 21

In larger or irregularly shaped lakes several smaller units will be more effective than one large unit. In a round, square or oval lake, place a spray type unit or an air diffuser in the center of the lake or over the deepest area, while an aspirator placed near the edge of the lake would generate circular flow. In long, thin lakes use multiple units or diffusers to generate circulation throughout the lake. If you are using a single unit, place it in the area that will give you the greatest amount of circulation, aerators in irregularly shaped lakes should be placed where they will generate maximum circulation. Use the appropriate unit for the appropriate area of the lake, streams and canals can best be aerated by using the horizontal aspirator.

ALTERNATIVE SOLUTIONS

Ozone is a powerful oxidant and disinfectant, the concept is in its relative infancy as far as lake management is concerned. At this time there is little or no university based data regarding ozone in our field and the International Ozone Association have no studies regarding ozone use for lake management. However it is possible to extrapolate data from the water treatment and wastewater industries and apply it to our industry.

Ozone is a highly unstable form of oxygen, its chemical sign is O_3 and is created when an oxygen molecule is split from O_2 to two O_1. These oxygen radicals are highly unstable and quickly attach to surrounding oxygen molecules to create O_3 the unstable ozone molecules will quickly revert back to oxygen soon after. The half-life of ozone in water is roughly 20 to 30 minutes and will last in water up to one hour depending on temperature and oxygen demand.

Ozone is created by either corona discharge or by ultraviolet light generators. Corona discharge is the method used for wastewater and water treatment and is able to produce an ozone/air mixture that ranges from 2 to 4% ozone, consuming 6 to 8 kilowatt hours to produce one kilogram of ozone. Ultraviolet light generators can produce an ozone/air mixture that is roughly .1% ozone, consuming 40 kilowatt hours to produce one kilogram of ozone. When comparing the systems, both capital and operational costs must be considered. From a practical view, consider the capital cost in terms of grams of ozone created per dollar, from an operational viewpoint consider energy costs to produce one kilogram of ozone.

Ozone's ability to oxide is tremendous. It is five times stronger than oxygen and over 50% more powerful than chlorine. As such, it has significant potential in lake management. Ozone is a strong disinfectant it's able to kill bacterial cells by piercing the cell wall and bursting the cell in a process known as ***lysing***. Ozone is over 3,000 times faster and 50% stronger than chlorine as a disinfectant, and reverts to harmless oxygen in short order.

In lake management we can look to ozone to provide solutions in the following scenarios: Algae control, Clarity enhancements, Effluent.

In one situation the clarity was 8in/20cm, after a week of corona discharge ozone treatment the clarity in the same lake exceeded 3ft/1m.

Ozone demand in the water is extremely high. Research indicates that with the small generators currently used in the market (<40 grams of ozone/hour), it is virtually impossible to sterilize a lake by putting in too much ozone. When sizing a system it is important to know the volume of the lake, source of the water, shape of the basin, and any other related detail. It's important to remember that the basin should be turned or mixed over 4 to 7 times per day.

Follow the following dosage levels to achieve satisfactory results:

Standard algae, odor, or clarity problems
1.8 grams/hour per 1,234 m^3 or acre foot

Moderate algae, odor, or clarity problems
2.57 grams/hour per 1,234 m^3 or acre foot

Effluent & severe problems
3.85 grams/hour per 1,234 m^3 or acre foot

Another form of biological control is the introduction of additional bacteria into the pond, otherwise known as ***bioaugmentation***. This is a very important tool for helping lower nutrient counts especially in effluent waters. Several companies commercially produce bacteria and they can be applied in either liquid or powder form. These aerobic bacteria consume oxygen and help speed the breakdown of nutrients. Studies have shown that by using aeration and bacteria in conjunction 1 to 6 inches or 2 to 15 cm of bottom sediment can be reduced in a single year. However pH and the chemical make up of your lake will determine if this approach is effective for you.

These products have been used for decades in wastewater treatment facilities and fish farms. In turf related lakes, the objectives are to reduce algae, improve clarity, eliminate odors and to break down the organic material in the sludge bed. This is partially achieved by lowering nutrients and suspended solids in the water column. Algae blooms are reduced through the redirection of nutrients. Phosphorus is absorbed into the bacteria's cell wall making it unavailable to algae, nitrogen is taken from the water through the nitrification cycle, while ammonia and nitrates are oxidized by dissolved oxygen. Basically the bacteria competes for the same nutrient needed by the algae and wins!

While visible results take several weeks, a 50% reduction in phosphorus and nitrogen occur within 1 to 2 days. In 3 to 4 days there is a significant reduction of odors and in 14 days clarity enhancements are noticeable. Algae should either be harvested or chemically treated before the addition of bacteria, if chemicals are used wait at least 48 hours before using bioaugmentation products (*Figure 22*).


Figure 22

Initial doses are required with lighter maintenance doses following periodically. The limiting factors with this approach are pH, temperature and dissolved oxygen. The pH should be between 6 and 9, while the water temperature should be between 55 to 100º F (12 to 40º C). The bacteria's metabolic rate falls with temperature and optimum results are achieved when the water temperature nears 86º F/30º C. Dissolved oxygen levels are critical to any aerobic bacteria activity, and this is especially the case when the bacterial population is artificially increased. *Aeration is a must if one is to see results from bioaugmentation.*


Figure 23a

Another proactive, preventative measure is the introduction of weed eating fish or grass carp such as the White Amur or Triploid Grass Carp (*Figure 23a*). These fish can be quite effective in keeping excessive weed growth under control. They are inexpensive over the long term and require no labor or upkeep once they are in the water. They can eat 2 to 3 times their body weight in a day, unfortunately they assimilate only a fraction of what they eat doubling their body weight in a year. The rest of the weed matter is returned to the lake as waste.

Stocking rates are twelve to sixteen 10in/20cm fish for every one surface acre or 4,000 m^2. Restocking is required every five years. They are indiscriminate feeders, growing to over 45 pounds/20 kilos (*Figure 23b*). However, be aware that their preferred foods are the most desirable aquatic plants and they will only eat algae if their preferred plants are not available. Many states regulate their use as they are a non-native species and destroy the habitat of native fish and disrupt the food chain. Also, by removing all of the aquatic plant growth in the pond a major source of oxygen is removed and odor and water quality problems can result.


Figure 23b

Barley straw has also been receiving attention as a possible cure for algae blooms. The concept requires that straw be distributed on the surface of the pond or placed in netting and then submerged (*Figure 24*). If sufficient dissolved oxygen levels are present the straw will begin to decompose, as this occurs it goes through several stages. During the final stage of decomposition the straw oxidizes to humic acids and other humic substances. It has been shown that when sunlight shines into water that contains dissolved oxygen and humic substances hydrogen peroxide is formed., low levels of peroxide are known to inhibit the growth of algae.


Figure 24

To date the only documented research has been done by Dr. Jonathan Newman, Aquatic Weed Research Unit, U.K. and the University of Florida. The study from England is written in scientific language, but several times in the report it returns to the conclusion that, *"Activity is only produced if the straw is rotting under well oxygenated conditions."* The University of Florida study produced inconclusive results that barley straw had any impact on algae. By adding straw to the water, we add more nutrient and vegetative matter that will convert to biomass, creating more oxygen demand. While there may be short term benefits in the long run the addition of more nutrient makes the lake more difficult to manage and creates additional biological imbalance.

A relatively new fad in water quality management is the burning of sulfur to treat irrigation water and lower the pH. Return water from the irrigation system is mixed in the irrigation lake where the sulfur dioxide (a cousin of sulfuric acid) will then lower the pH of some lake water 2 to 2.5pH. However the sulfur dioxide will attach to the dissolved oxygen in the pond and can lower the oxygen into crisis levels, therefore supplemental aeration must be used in conjunction with these systems. The typical system costs $50,000 and burns $7,000 worth of elemental sulfur per year and a sulfur odor smell is produced into the air when the system is operational. From a lake manager's vantage point, this tool is targeted more at a symptom, algae - than at the cause, poor water quality. The EPA is currently looking into the environmental impact of these systems.

'Reactive' means we wait for the lake to lose ecological balance before we implement a management program. Reactive management tends to be crisis driven and less environmentally friendly, not to mention they are usually more costly. However they can be a necessary and important tool for the lake manager.

When designing your lake management program be sure to align the proper management method with the ecological needs of the lake. Using a reactive tool for prevention will not achieve the desired results. Likewise, preventative tools will have less impact once the lake is in crisis.


Figure 25

The harvester is a device that removes floating weeds, algae, and debris from the lake by skimming it off the surface (*Figure 25*). This is an extremely effective tool and removes the plants and the associated nutrients from the lake permanently. However the process is expensive and short term in effect. We stated that green and blue green algae have a two-week life, thus the use of a harvester for ongoing algae control would prove cost prohibitive.

When a lake becomes eutrophic and a significant sludge/nutrient bed is established at the lake bottom, there may be no alternative but to dredge the lake. Dredges are large floating machines that must be transported across the golf course or site, where there is a risk of damage being done to the turf and greens

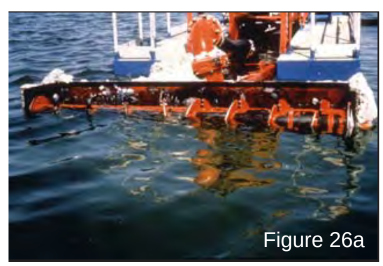


Figure 26a

The dredge employs a large auger type screw, much like a snow blower (*Figure 26a*). The screw is lowered into the water and begins to scrape up the sediment. These sediments will have a high degree of partially degraded, anoxic materials and it will prove quite odiferous. The debris material is then pumped to the shore where it must be removed from the site (*Figure 26b*), often the slurry or debris can contain heavy metals and is sometimes considered hazardous waste. The average machine can


Figure 26b

remove 3ft/1m depth of sludge material from a one acre lake\4,000m^2 in 40 hours. By removing sediments and plant material, a potential nutrient source is removed from the pond, not to mention mechanical control is expensive, labor intensive, and needs to be repeated often as plants grow back.

Chemical control is a widely used method of aquatic plant control, algaecides and herbicides are applied to the pond or lake to kill the algae and plants. The benefits of chemical control methods are that they are fairly quick and can be used to control stubborn problems or to eliminate specific types of unwanted plants. Most aquatic algaecides and herbicides are copper-based products and are available in liquid (*Figure 27a*) or granular form (*Figure 27b*). Liquid algaecides/herbicides are used for plants throughout the entire water column, while granular forms are typically used to treat problems at the bottom.


Figure 27a

Figure 27b

Dosage levels are dependent on the alkalinity of a lake, particularly with copper based products. *Water chemistry should be tested before using any chemical.*

Chemicals may be applied by hand, however great care must be used to insure they are handled properly, in larger lakes they may be applied from a spray boat (*Figure 27c*). Many states and countries require that the applicator is licensed, as it is important to understand the desired dosage and proper application technique. Be sure to use EPA or government approved chemicals only. Many herbicides are copper based products that add heavy metals to the water table, if there is prolonged use of these chemicals there will be a toxic build up of copper in the lakes. It is essential that chemicals are only used in static lakes.

Manufacturers claim that herbicides kill a “broad range” of aquatic plants and some kill on contact. When “broad range” killers are introduced into the aquatic ecosystem beneficial plants that fix nitrogen and phosphorus may be killed with nuisance algae or weeds. Herbicides do not discriminate and beneficial bacteria and protozoa may be damaged in the process as well.


Figure 27c

There are other side effects, herbicides kill plants and algae that then sink to the pond bottom and begin to decompose creating the potential by-product of oxygen depletion, fish kills and aquatic odors. In addition, herbicides kill the beneficial bacteria which help to decompose nutrients. As these herbicides are released into the water, they accelerate oxygen consumption again creating an oxygen depletion or stress situation.

As stated earlier, it is important to hire a licensed applicator when using chemicals in a pond. Since these products are herbicides there is a risk to turf and land plants if the treated water is used to irrigate. Mechanical aeration used in conjunction with chemicals has been proven to reduce the amount of chemicals needed, moreover mechanical aeration and limited chemicals can offer a strong proactive approach with reactive measures used when necessary.

CLOSING SUMMARY

Water quality management is a science. A better understanding of the aquatic ecosystem and the causes and effects of the interrelated factors are critical to successfully manage any pond or lake. Every lake or pond is a unique ecosystem that requires the proper analysis and understanding. *NO* two lakes are the same and as such no one management program will provide the same results on two different lakes. The delicate balance between temperature, nutrients, and oxygen plays an important role in creating the management program for any lake or pond.

The fundamentals of designing great lake management programs on your properties are fairly straightforward. The first step is to identify the causes, not the symptoms of chronic lake management problems. Consider the essential factors; is your problem light, temperature, nutrient, or oxygen related? Most of the problems that lakes suffer from are a combination of all three of these factors.

Next, analyze the basin configuration. Do you have the necessary size, shape and depth to sustain a healthy ecosystem, as it's almost impossible to make up for a bad design.

After you have identified the chronic problem and the root causes, you are ready to craft a solution. Minimize light and heat issues with lake-dye and mixing. If you don't have the necessary depth it may be necessary to dredge. Nutrient related problems need to be addressed by minimizing the nutrients that runoff into the lake and by lowering nutrient levels in the lake. No fertilize zones, slow release fertilizers, swales, wetlands and buffer plants will help to reduce new loading in the lake. Aeration, bioaugmentation, and weed eating fish help lower nutrient levels in the lake itself.

Use proactive tools as your ongoing management program, reserving the reactive tools for when the lake goes into crisis. Harvesting, dredging, and chemicals are all effective but none of these are practical day-to-day solutions.

Use complimentary practices when designing your program. For instance there are cases where the use of aeration and lake-dye are able to completely solve algae problems in just six weeks. There is no single stand alone tool for lake management and a solution designed around controlling all of the essential factors will have the greatest degree of success.

Lake management is a continuum. The longer a proactive management program is in place the greater the benefit you will see. Biological solutions will garner results on a gradual, long-term basis.

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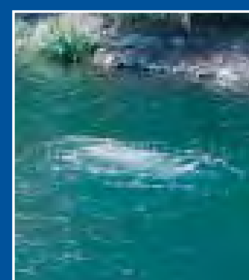
Website: http:\\www.otterbine.com



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Appendix G - Penstock Injection OPCC

Prepared by: KJC Checked: WJF

Gomez and Sullivan Engineers, D.P.C. Project No: 2179

Prepared for:

NYPA

OPINION OF PROBABLE CONSTRUCTION COST 1/22/2021

Project: **Jarvis DO Enhancement Study**

Estimate for: **Penstock Air Injection Through 12" PVC Vents - 900 cfs discharge (1260 cfm air flow)[6]**

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$255,000.00	$25,500
	Direct Drive, 50 HP - Variable Drive Rotary Screw Air Compressors (~37 - 212 CFM each)	3	EA	$35,000	$105,000
	Direct Drive, 150 HP - Variable Drive Rotary Screw Air Compressors (~127 - 624 CFM each)	1	EA	$85,000	$85,000
	1-1/4" - Nitrile Air Hose	750	LF	$20	$15,000
	Electrical Connections	1	LS	$35,000	$35,000
	SCADA and Control System Adjustments	1	LS	$15,000	$15,000

Subtotal Direct Cost	**$280,500**
Contingency Allowance (40%)[2]	$112,200
Total Direct Cost[3]	**$393,000**
Engineering, Administration, Permitting and Construction Management	$50,000
Total OPCC $2021	**$443,000**

Notes:
1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 40%.
3. Rounded to the nearest $1,000.
4. Engineers OPCC is based on generally available databases (e.g. Means) and in-house pricing information for the local market. Competitive bidding environments, unknown field conditions, and other local market factors may contritbute to variances in costs.
5. A method for securing the hose through the vents has yet to be determined.
6. An air flow of 2,720 CFM would be required for injection into the penstock to mitigate a dissolved oxygen deficit of 2.4 mg/L in the tailrace for a powerhouse flow of 900 cfs.

Prepared by: KJC Checked: WJF

Gomez and Sullivan Engineers, D.P.C. Project No: 2179

Prepared for:

NYPA

OPINION OF PROBABLE CONSTRUCTION COST 1/22/2021

Project: **Jarvis DO Enhancement Study**

Estimate for: **Penstock Air Injection Through 12" PVC Vents - 1800 cfs discharge (2,720 cfm air flow)[6]**

Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$465,000.00	$46,500
	Direct Drive, 50 HP - Variable Drive Rotary Screw Air Compressors (~37 - 212 CFM each)	4	EA	$35,000	$140,000
	Direct Drive, 150 HP - Variable Drive Rotary Screw Air Compressors (~127 - 624 CFM each)	3	EA	$85,000	$255,000
	1-1/4" - Nitrile Air Hose	1000	LF	$20	$20,000
	Electrical Connections	1	LS	$35,000	$35,000
	SCADA and Control System Adjustments	1	LS	$15,000	$15,000

Subtotal Direct Cost	**$511,500**
Contingency Allowance (40%)[2]	$204,600
Total Direct Cost[3]	**$716,000**
Engineering, Administration, Permitting and Construction Management	$50,000
Total OPCC $2021	**$766,000**

Notes:
1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 40%.
3. Rounded to the nearest $1,000.
4. Engineers OPCC is based on generally available databases (e.g. Means) and in-house pricing information for the local market. Competitive bidding environments, unknown field conditions, and other local market factors may contritbute to variances in costs.
5. A method for securing the hose through the vents has yet to be determined.
6. An air flow of 2,720 CFM would be required for injection into the penstock to mitigate a dissolved oxygen deficit of 2.4 mg/L in the tailrace for a powerhouse flow of 1800 cfs.

Appendix H – Spreadsheet Outflow Duration Model Backup

Existing - June -20 cfs Gate No. 4 Leakage							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	13,062	20	1,800	1,820	7,438.27	7,400.00	-
1.0%	3,239	20	1,800	1,820	7,438.27	7,400.00	74.00
2.0%	2,512	20	1,800	1,820	7,438.27	7,400.00	74.00
3.0%	2,238	20	1,800	1,820	7,438.27	7,400.00	74.00
4.0%	1,903	20	1,800	1,820	7,438.27	7,400.00	74.00
5.0%	1,731	20	1,711	1,731	7,068.48	7,068.48	72.34
6.0%	1,652	20	1,632	1,652	6,742.12	6,742.12	69.05
7.0%	1,620	20	1,600	1,620	6,610.75	6,610.75	66.76
8.0%	1,592	20	1,572	1,592	6,497.68	6,497.68	65.54
9.0%	1,533	20	1,513	1,533	6,252.63	6,252.63	63.75
10.0%	1,497	20	1,477	1,497	6,103.64	6,103.64	61.78
11.0%	1,477	20	1,457	1,477	6,021.80	6,021.80	60.63
12.0%	1,449	20	1,429	1,449	5,906.66	5,906.66	59.64
13.0%	1,407	20	1,387	1,407	5,730.50	5,730.50	58.19
14.0%	1,399	20	1,379	1,399	5,696.97	5,696.97	57.14
15.0%	1,390	20	1,370	1,390	5,661.51	5,661.51	56.79
16.0%	1,377	20	1,357	1,377	5,606.10	5,606.10	56.34
17.0%	1,330	20	1,310	1,330	5,415.42	5,415.42	55.11
18.0%	1,263	20	1,243	1,263	5,134.87	5,134.87	52.75
19.0%	1,208	20	1,188	1,208	4,910.45	4,910.45	50.23
20.0%	1,184	20	1,164	1,184	4,810.50	4,810.50	48.60
21.0%	1,156	20	1,136	1,156	4,693.59	4,693.59	47.52
22.0%	1,113	20	1,093	1,113	4,517.28	4,517.28	46.05
23.0%	1,096	20	1,076	1,096	4,447.85	4,447.85	44.83
24.0%	1,081	20	1,061	1,081	4,385.15	4,385.15	44.17
25.0%	1,048	20	1,028	1,048	4,246.53	4,246.53	43.16
26.0%	961	20	941	961	3,886.68	3,886.68	40.67
27.0%	940	20	920	940	3,800.49	3,800.49	38.44
28.0%	925	20	905	925	3,739.60	3,739.60	37.70
29.0%	908	20	888	908	3,671.39	3,671.39	37.05
30.0%	898	20	878	898	3,627.26	3,627.26	36.49
31.0%	867	20	847	867	3,499.56	3,499.56	35.63
32.0%	795	20	775	795	3,201.68	3,201.68	33.51
33.0%	767	20	747	767	3,086.42	3,086.42	31.44
34.0%	719	20	699	719	2,887.16	2,887.16	29.87
35.0%	702	20	682	702	2,819.72	2,819.72	28.53
36.0%	697	20	677	697	2,797.62	2,797.62	28.09
37.0%	695	20	675	695	2,790.13	2,790.13	27.94
38.0%	678	20	658	678	2,718.39	2,718.39	27.54
39.0%	652	20	632	652	2,612.50	2,612.50	26.65
40.0%	618	20	598	618	2,470.04	2,470.04	25.41
41.0%	611	20	591	611	2,443.61	2,443.61	24.57
42.0%	610	20	590	610	2,439.67	2,439.67	24.42
43.0%	609	20	589	609	2,435.02	2,435.02	24.37
44.0%	607	20	587	607	2,427.27	2,427.27	24.31
45.0%	605	20	585	605	2,419.27	2,419.27	24.23
46.0%	604	20	584	604	2,413.77	2,413.77	24.17
47.0%	604	20	584	604	2,412.69	2,412.69	24.13
48.0%	603	20	583	603	2,409.17	2,409.17	24.11
49.0%	602	20	582	602	2,407.07	2,407.07	24.08
50.0%	602	20	582	602	2,405.47	2,405.47	24.06
51.0%	602	20	582	602	2,405.04	2,405.04	24.05
52.0%	601	20	581	601	2,402.93	2,402.93	24.04
53.0%	601	20	581	601	2,400.96	2,400.96	24.02
54.0%	601	20	581	601	2,400.71	2,400.71	24.01
55.0%	600	20	580	600	2,396.78	2,396.78	23.99
56.0%	600	20	580	600	2,395.49	2,395.49	23.96
57.0%	599	20	579	599	2,392.97	2,392.97	23.94
58.0%	599	20	579	599	2,392.38	2,392.38	23.93
59.0%	598	20	578	598	2,388.50	2,388.50	23.90
60.0%	597	20	577	597	2,384.10	2,384.10	23.86
61.0%	595	20	575	595	2,378.03	2,378.03	23.81
62.0%	593	20	573	593	2,369.60	2,369.60	23.74
63.0%	590	20	570	590	2,355.78	2,355.78	23.63
64.0%	584	20	564	584	2,330.16	2,330.16	23.43
65.0%	580	20	560	580	2,312.37	2,312.37	23.21
66.0%	577	20	557	577	2,301.16	2,301.16	23.07
67.0%	572	20	552	572	2,281.33	2,281.33	22.91
68.0%	570	20	550	570	2,274.51	2,274.51	22.78
69.0%	568	20	548	568	2,263.25	2,263.25	22.69
70.0%	564	20	544	564	2,247.16	2,247.16	22.55
71.0%	558	20	538	558	2,223.91	2,223.91	22.36
72.0%	547	20	527	547	2,177.91	2,177.91	22.01
73.0%	533	20	513	533	2,120.38	2,120.38	21.49
74.0%	531	20	511	531	2,111.89	2,111.89	21.16
75.0%	524	20	504	524	2,084.39	2,084.39	20.98
76.0%	515	20	495	515	2,044.58	2,044.58	20.64
77.0%	511	20	491	511	2,028.94	2,028.94	20.37
78.0%	506	20	486	506	2,008.83	2,008.83	20.19
79.0%	505	20	485	505	2,003.36	2,003.36	20.06
80.0%	502	20	482	502	1,991.80	1,991.80	19.98
81.0%	501	20	481	501	1,987.67	1,987.67	19.90
82.0%	499	20	479	499	1,980.34	1,980.34	19.84
83.0%	492	20	472	492	1,950.61	1,950.61	19.65
84.0%	481	20	461	481	1,903.38	1,903.38	19.27
85.0%	465	20	445	465	1,838.78	1,838.78	18.71
86.0%	459	20	439	459	1,814.36	1,814.36	18.27
87.0%	456	20	436	456	1,801.08	1,801.08	18.08
88.0%	450	20	430	450	1,778.33	1,778.33	17.90
89.0%	445	20	425	445	1,754.41	1,754.41	17.66
90.0%	409	20	389	409	1,606.57	1,606.57	16.80
91.0%	404	20	384	404	1,587.78	1,587.78	15.97
92.0%	402	20	382	402	1,580.06	1,580.06	15.84
93.0%	399	20	379	399	1,566.17	1,566.17	15.73
94.0%	329	20	309	329	1,275.48	1,275.48	14.21
95.0%	311	20	-		-	-	6.38
96.0%	310	20	-		-	-	-
97.0%	307	20	-		-	-	-
98.0%	306	20	-		-	-	-
99.0%	302	20	-		-	-	-
100.0%	245	20	-		-	-	-

Proposed - June -Gate No. 4 Proposed Releases							
Percentage of Time Equaled or Exceeded	Historic Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Total Release (Powerhouse + Gate No. 4) (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	13,062	417	348	765	1,438.07	1,438.07	-
1.0%	3,239	417	348	765	1,438.07	1,438.07	14.38
2.0%	2,512	417	348	765	1,438.07	1,438.07	14.38
3.0%	2,238	417	348	765	1,438.07	1,438.07	14.38
4.0%	1,903	417	348	765	1,438.07	1,438.07	14.38
5.0%	1,731	417	348	765	1,438.07	1,438.07	14.38
6.0%	1,652	417	348	765	1,438.07	1,438.07	14.38
7.0%	1,620	417	348	765	1,438.07	1,438.07	14.38
8.0%	1,592	417	348	765	1,438.07	1,438.07	14.38
9.0%	1,533	417	348	765	1,438.07	1,438.07	14.38
10.0%	1,497	417	348	765	1,438.07	1,438.07	14.38
11.0%	1,477	417	348	765	1,438.07	1,438.07	14.38
12.0%	1,449	417	348	765	1,438.07	1,438.07	14.38
13.0%	1,407	417	348	765	1,438.07	1,438.07	14.38
14.0%	1,399	417	348	765	1,438.07	1,438.07	14.38
15.0%	1,390	417	348	765	1,438.07	1,438.07	14.38
16.0%	1,377	417	348	765	1,438.07	1,438.07	14.38
17.0%	1,330	417	348	765	1,438.07	1,438.07	14.38
18.0%	1,263	417	348	765	1,438.07	1,438.07	14.38
19.0%	1,208	417	348	765	1,438.07	1,438.07	14.38
20.0%	1,184	417	348	765	1,438.07	1,438.07	14.38
21.0%	1,156	417	348	765	1,438.07	1,438.07	14.38
22.0%	1,113	417	348	765	1,438.07	1,438.07	14.38
23.0%	1,096	417	348	765	1,438.07	1,438.07	14.38
24.0%	1,081	417	348	765	1,438.07	1,438.07	14.38
25.0%	1,048	417	348	765	1,438.07	1,438.07	14.38
26.0%	961	417	348	765	1,438.07	1,438.07	14.38
27.0%	940	417	348	765	1,438.07	1,438.07	14.38
28.0%	925	417	348	765	1,438.07	1,438.07	14.38
29.0%	908	417	348	765	1,438.07	1,438.07	14.38
30.0%	898	417	348	765	1,438.07	1,438.07	14.38
31.0%	867	417	348	765	1,438.07	1,438.07	14.38
32.0%	795	417	348	765	1,438.07	1,438.07	14.38
33.0%	767	417	348	765	1,438.07	1,438.07	14.38
34.0%	719	392	327	719	1,349.91	1,349.91	13.94
35.0%	702	383	319	702	1,319.26	1,319.26	13.35
36.0%	697	380	317	697	1,309.21	1,309.21	13.14
37.0%	695	379	316	695	1,305.81	1,305.81	13.08
38.0%	678	370	308	678	1,273.20	1,273.20	12.90
39.0%	652		-				12.73
40.0%	618		-				
41.0%	611		-		-	-	-
42.0%	610		-		-	-	-
43.0%	609		-		-	-	-
44.0%	607		-		-	-	-
45.0%	605		-		-	-	-
46.0%	604		-		-	-	-
47.0%	604		-		-	-	-
48.0%	603		-		-	-	-
49.0%	602		-		-	-	-
50.0%	602		-		-	-	-
51.0%	602		-		-	-	-
52.0%	601		-		-	-	-
53.0%	601		-		-	-	-
54.0%	601		-		-	-	-
55.0%	600		-		-	-	-
56.0%	600		-		-	-	-
57.0%	599		-		-	-	-
58.0%	599		-		-	-	-
59.0%	598		-		-	-	-
60.0%	597		-		-	-	-
61.0%	595		-		-	-	-
62.0%	593		-		-	-	-
63.0%	590		-		-	-	-
64.0%	584		-		-	-	-
65.0%	580		-		-	-	-
66.0%	577		-		-	-	-
67.0%	572		-		-	-	-
68.0%	570		-		-	-	-
69.0%	568		-		-	-	-
70.0%	564		-		-	-	-
71.0%	558		-		-	-	-
72.0%	547		-		-	-	-
73.0%	533		-		-	-	-
74.0%	531		-		-	-	-
75.0%	524		-		-	-	-
76.0%	515		-		-	-	-
77.0%	511		-		-	-	-
78.0%	506		-		-	-	-
79.0%	505		-		-	-	-
80.0%	502		-		-	-	-
81.0%	501		-		-	-	-
82.0%	499		-		-	-	-
83.0%	492		-		-	-	-
84.0%	481		-		-	-	-
85.0%	465		-		-	-	-
86.0%	459		-		-	-	-
87.0%	456		-		-	-	-
88.0%	450		-		-	-	-
89.0%	445		-		-	-	-
90.0%	409		-		-	-	-
91.0%	404		-		-	-	-
92.0%	402		-		-	-	-
93.0%	399		-		-	-	-
94.0%	329		-		-	-	-
95.0%	311		-		-	-	-
96.0%	310		-		-	-	-
97.0%	307		-		-	-	-
98.0%	306		-		-	-	-
99.0%	302		-		-	-	-
100.0%	245		-		-	-	-

Existing - July -20 cfs Gate No. 4 Leakage							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	7,696	20	1,800	1,820	7,438.27	7,400.00	-
1.0%	2,862	20	1,800	1,820	7,438.27	7,400.00	74.00
2.0%	2,164	20	1,800	1,820	7,438.27	7,400.00	74.00
3.0%	1,862	20	1,800	1,820	7,438.27	7,400.00	74.00
4.0%	1,716	20	1,696	1,716	7,008.70	7,008.70	72.04
5.0%	1,670	20	1,650	1,670	6,818.80	6,818.80	69.14
6.0%	1,598	20	1,578	1,598	6,518.82	6,518.82	66.69
7.0%	1,478	20	1,458	1,478	6,024.12	6,024.12	62.71
8.0%	1,399	20	1,379	1,399	5,698.42	5,698.42	58.61
9.0%	1,318	20	1,298	1,318	5,365.87	5,365.87	55.32
10.0%	1,209	20	1,189	1,209	4,914.91	4,914.91	51.40
11.0%	1,182	20	1,162	1,182	4,800.07	4,800.07	48.57
12.0%	1,163	20	1,143	1,163	4,721.27	4,721.27	47.61
13.0%	1,088	20	1,068	1,088	4,411.48	4,411.48	45.66
14.0%	961	20	941	961	3,886.97	3,886.97	41.49
15.0%	919	20	899	919	3,713.06	3,713.06	38.00
16.0%	843	20	823	843	3,400.13	3,400.13	35.57
17.0%	810	20	790	810	3,264.22	3,264.22	33.32
18.0%	769	20	749	769	3,093.82	3,093.82	31.79
19.0%	705	20	685	705	2,828.66	2,828.66	29.61
20.0%	701	20	681	701	2,814.36	2,814.36	28.22
21.0%	699	20	679	699	2,805.88	2,805.88	28.10
22.0%	698	20	678	698	2,800.26	2,800.26	28.03
23.0%	682	20	662	682	2,733.57	2,733.57	27.67
24.0%	660	20	640	660	2,644.64	2,644.64	26.89
25.0%	651	20	631	651	2,607.36	2,607.36	26.26
26.0%	630	20	610	630	2,522.42	2,522.42	25.65
27.0%	618	20	598	618	2,472.32	2,472.32	24.97
28.0%	612	20	592	612	2,447.12	2,447.12	24.60
29.0%	608	20	588	608	2,428.27	2,428.27	24.38
30.0%	605	20	585	605	2,417.06	2,417.06	24.23
31.0%	603	20	583	603	2,409.17	2,409.17	24.13
32.0%	602	20	582	602	2,406.94	2,406.94	24.08
33.0%	602	20	582	602	2,403.30	2,403.30	24.05
34.0%	601	20	581	601	2,399.26	2,399.26	24.01
35.0%	599	20	579	599	2,393.06	2,393.06	23.96
36.0%	598	20	578	598	2,388.51	2,388.51	23.91
37.0%	597	20	577	597	2,382.71	2,382.71	23.86
38.0%	595	20	575	595	2,375.29	2,375.29	23.79
39.0%	593	20	573	593	2,366.16	2,366.16	23.71
40.0%	589	20	569	589	2,352.97	2,352.97	23.60
41.0%	587	20	567	587	2,343.02	2,343.02	23.48
42.0%	585	20	565	585	2,334.63	2,334.63	23.39
43.0%	582	20	562	582	2,320.66	2,320.66	23.28
44.0%	581	20	561	581	2,316.36	2,316.36	23.19
45.0%	577	20	557	577	2,303.14	2,303.14	23.10
46.0%	574	20	554	574	2,287.47	2,287.47	22.95
47.0%	571	20	551	571	2,278.24	2,278.24	22.83
48.0%	568	20	548	568	2,263.80	2,263.80	22.71
49.0%	565	20	545	565	2,251.46	2,251.46	22.58
50.0%	561	20	541	561	2,233.55	2,233.55	22.43
51.0%	556	20	536	556	2,213.82	2,213.82	22.24
52.0%	551	20	531	551	2,195.28	2,195.28	22.05
53.0%	549	20	529	549	2,187.96	2,187.96	21.92
54.0%	549	20	529	549	2,186.03	2,186.03	21.87
55.0%	543	20	523	543	2,161.05	2,161.05	21.74
56.0%	540	20	520	540	2,147.99	2,147.99	21.55
57.0%	535	20	515	535	2,128.28	2,128.28	21.38
58.0%	530	20	510	530	2,109.20	2,109.20	21.19
59.0%	529	20	509	529	2,102.11	2,102.11	21.06
60.0%	526	20	506	526	2,092.56	2,092.56	20.97
61.0%	525	20	505	525	2,086.85	2,086.85	20.90
62.0%	522	20	502	522	2,075.74	2,075.74	20.81
63.0%	519	20	499	519	2,062.52	2,062.52	20.69
64.0%	515	20	495	515	2,044.43	2,044.43	20.53
65.0%	509	20	489	509	2,020.66	2,020.66	20.33
66.0%	504	20	484	504	2,001.82	2,001.82	20.11
67.0%	502	20	482	502	1,991.07	1,991.07	19.96
68.0%	500	20	480	500	1,983.54	1,983.54	19.87
69.0%	496	20	476	496	1,966.56	1,966.56	19.75
70.0%	484	20	464	484	1,916.70	1,916.70	19.42
71.0%	477	20	457	477	1,887.39	1,887.39	19.02
72.0%	454	20	434	454	1,793.45	1,793.45	18.40
73.0%	452	20	432	452	1,785.19	1,785.19	17.89
74.0%	449	20	429	449	1,772.29	1,772.29	17.79
75.0%	437	20	417	437	1,723.20	1,723.20	17.48
76.0%	430	20	410	430	1,692.62	1,692.62	17.08
77.0%	413	20	393	413	1,624.06	1,624.06	16.58
78.0%	410	20	390	410	1,611.63	1,611.63	16.18
79.0%	405	20	385	405	1,590.96	1,590.96	16.01
80.0%	404	20	384	404	1,587.97	1,587.97	15.89
81.0%	404	20	384	404	1,586.83	1,586.83	15.87
82.0%	403	20	383	403	1,582.70	1,582.70	15.85
83.0%	403	20	383	403	1,582.56	1,582.56	15.83
84.0%	402	20	382	402	1,578.57	1,578.57	15.81
85.0%	401	20	381	401	1,576.11	1,576.11	15.77
86.0%	401	20	381	401	1,574.43	1,574.43	15.75
87.0%	401	20	381	401	1,572.61	1,572.61	15.74
88.0%	399	20	379	399	1,566.02	1,566.02	15.69
89.0%	398	20	378	398	1,561.81	1,561.81	15.64
90.0%	396	20	376	396	1,553.67	1,553.67	15.58
91.0%	393	20	373	393	1,542.39	1,542.39	15.48
92.0%	385	20	365	385	1,510.15	1,510.15	15.26
93.0%	333	20	313	333	1,292.98	1,292.98	14.02
94.0%	326	20	306	326	1,262.62	1,262.62	12.78
95.0%	252	20	-		-	-	6.31
96.0%	251	20	-		-	-	-
97.0%	247	20	-		-	-	-
98.0%	245	20	-		-	-	-
99.0%	242	20	-		-	-	-
100.0%	178	20	-		-	-	-

Proposed - July - Gate No. 4 Proposed Releases

Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	7,696	417	348	765	1,438.07	1,438.07	-
1.0%	2,862	417	348	765	1,438.07	1,438.07	14.38
2.0%	2,164	417	348	765	1,438.07	1,438.07	14.38
3.0%	1,862	417	348	765	1,438.07	1,438.07	14.38
4.0%	1,716	417	348	765	1,438.07	1,438.07	14.38
5.0%	1,670	417	348	765	1,438.07	1,438.07	14.38
6.0%	1,598	417	348	765	1,438.07	1,438.07	14.38
7.0%	1,478	417	348	765	1,438.07	1,438.07	14.38
8.0%	1,399	417	348	765	1,438.07	1,438.07	14.38
9.0%	1,318	417	348	765	1,438.07	1,438.07	14.38
10.0%	1,209	417	348	765	1,438.07	1,438.07	14.38
11.0%	1,182	417	348	765	1,438.07	1,438.07	14.38
12.0%	1,163	417	348	765	1,438.07	1,438.07	14.38
13.0%	1,088	417	348	765	1,438.07	1,438.07	14.38
14.0%	961	417	348	765	1,438.07	1,438.07	14.38
15.0%	919	417	348	765	1,438.07	1,438.07	14.38
16.0%	843	417	348	765	1,438.07	1,438.07	14.38
17.0%	810	417	348	765	1,438.07	1,438.07	14.38
18.0%	769	417	348	765	1,438.07	1,438.07	14.38
19.0%	705	384	320	705	1,323.32	1,323.32	13.81
20.0%	701	382	319	701	1,316.82	1,316.82	13.20
21.0%	699	381	318	699	1,312.97	1,312.97	13.15
22.0%	698	381	317	698	1,310.41	1,310.41	13.12
23.0%	682	372	310	682	1,280.10	1,280.10	12.95
24.0%	660	360	300	660	1,239.68	1,239.68	12.60
25.0%	651		-		-	-	6.20
26.0%	630		-		-	-	-
27.0%	618		-		-	-	-
28.0%	612		-		-	-	-
29.0%	608		-		-	-	-
30.0%	605		-		-	-	-
31.0%	603		-		-	-	-
32.0%	602		-		-	-	-
33.0%	602		-		-	-	-
34.0%	601		-		-	-	-
35.0%	599		-		-	-	-
36.0%	598		-		-	-	-
37.0%	597		-		-	-	-
38.0%	595		-		-	-	-
39.0%	593		-		-	-	-
40.0%	589		-		-	-	-
41.0%	587		-		-	-	-
42.0%	585		-		-	-	-
43.0%	582		-		-	-	-
44.0%	581		-		-	-	-
45.0%	577		-		-	-	-
46.0%	574		-		-	-	-
47.0%	571		-		-	-	-
48.0%	568		-		-	-	-
49.0%	565		-		-	-	-
50.0%	561		-		-	-	-
51.0%	556		-		-	-	-
52.0%	551		-		-	-	-
53.0%	549		-		-	-	-
54.0%	549		-		-	-	-
55.0%	543		-		-	-	-
56.0%	540		-		-	-	-
57.0%	535		-		-	-	-
58.0%	530		-		-	-	-
59.0%	529		-		-	-	-
60.0%	526		-		-	-	-
61.0%	525		-		-	-	-
62.0%	522		-		-	-	-
63.0%	519		-		-	-	-
64.0%	515		-		-	-	-
65.0%	509		-		-	-	-
66.0%	504		-		-	-	-
67.0%	502		-		-	-	-
68.0%	500		-		-	-	-
69.0%	496		-		-	-	-
70.0%	484		-		-	-	-
71.0%	477		-		-	-	-
72.0%	454		-		-	-	-
73.0%	452		-		-	-	-
74.0%	449		-		-	-	-
75.0%	437		-		-	-	-
76.0%	430		-		-	-	-
77.0%	413		-		-	-	-
78.0%	410		-		-	-	-
79.0%	405		-		-	-	-
80.0%	404		-		-	-	-
81.0%	404		-		-	-	-
82.0%	403		-		-	-	-
83.0%	403		-		-	-	-
84.0%	402		-		-	-	-
85.0%	401		-		-	-	-
86.0%	401		-		-	-	-
87.0%	401		-		-	-	-
88.0%	399		-		-	-	-
89.0%	398		-		-	-	-
90.0%	396		-		-	-	-
91.0%	393		-		-	-	-
92.0%	385		-		-	-	-
93.0%	333		-		-	-	-
94.0%	326		-		-	-	-
95.0%	252		-		-	-	-
96.0%	251		-		-	-	-
97.0%	247		-		-	-	-
98.0%	245		-		-	-	-
99.0%	242		-		-	-	-
100.0%	178		-		-	-	-

Existing - August -20 cfs Gate No. 4 Leakage							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	2,311	20	1,800	1,820	7,438.27	7,400.00	-
1.0%	1,765	20	1,745	1,765	7,212.95	7,212.95	73.06
2.0%	1,413	20	1,393	1,413	5,757.64	5,757.64	64.85
3.0%	1,353	20	1,333	1,353	5,509.38	5,509.38	56.34
4.0%	1,238	20	1,218	1,238	5,032.70	5,032.70	52.71
5.0%	1,015	20	995	1,015	4,113.62	4,113.62	45.73
6.0%	885	20	865	885	3,575.53	3,575.53	38.45
7.0%	849	20	829	849	3,426.11	3,426.11	35.01
8.0%	814	20	794	814	3,280.50	3,280.50	33.53
9.0%	806	20	786	806	3,246.94	3,246.94	32.64
10.0%	800	20	780	800	3,223.42	3,223.42	32.35
11.0%	798	20	778	798	3,214.35	3,214.35	32.19
12.0%	792	20	772	792	3,191.55	3,191.55	32.03
13.0%	780	20	760	780	3,141.62	3,141.62	31.67
14.0%	767	20	747	767	3,088.50	3,088.50	31.15
15.0%	761	20	741	761	3,063.61	3,063.61	30.76
16.0%	758	20	738	758	3,051.03	3,051.03	30.57
17.0%	754	20	734	754	3,033.16	3,033.16	30.42
18.0%	751	20	731	751	3,021.81	3,021.81	30.27
19.0%	719	20	699	719	2,889.15	2,889.15	29.55
20.0%	708	20	688	708	2,843.68	2,843.68	28.66
21.0%	701	20	681	701	2,815.22	2,815.22	28.29
22.0%	700	20	680	700	2,810.67	2,810.67	28.13
23.0%	699	20	679	699	2,806.33	2,806.33	28.09
24.0%	696	20	676	696	2,793.81	2,793.81	28.00
25.0%	691	20	671	691	2,774.19	2,774.19	27.84
26.0%	688	20	668	688	2,759.14	2,759.14	27.67
27.0%	683	20	663	683	2,740.18	2,740.18	27.50
28.0%	680	20	660	680	2,729.32	2,729.32	27.35
29.0%	664	20	644	664	2,662.94	2,662.94	26.96
30.0%	662	20	642	662	2,652.50	2,652.50	26.58
31.0%	656	20	636	656	2,627.03	2,627.03	26.40
32.0%	654	20	634	654	2,619.26	2,619.26	26.23
33.0%	652	20	632	652	2,611.65	2,611.65	26.15
34.0%	651	20	631	651	2,607.53	2,607.53	26.10
35.0%	649	20	629	649	2,600.35	2,600.35	26.04
36.0%	646	20	626	646	2,587.47	2,587.47	25.94
37.0%	617	20	597	617	2,465.62	2,465.62	25.27
38.0%	602	20	582	602	2,405.99	2,405.99	24.36
39.0%	598	20	578	598	2,387.01	2,387.01	23.97
40.0%	581	20	561	581	2,320.15	2,320.15	23.54
41.0%	580	20	560	580	2,313.04	2,313.04	23.17
42.0%	565	20	545	565	2,253.73	2,253.73	22.83
43.0%	555	20	535	555	2,212.45	2,212.45	22.33
44.0%	551	20	531	551	2,192.85	2,192.85	22.03
45.0%	540	20	520	540	2,149.66	2,149.66	21.71
46.0%	527	20	507	527	2,094.54	2,094.54	21.22
47.0%	519	20	499	519	2,063.49	2,063.49	20.79
48.0%	513	20	493	513	2,038.66	2,038.66	20.51
49.0%	500	20	480	500	1,983.74	1,983.74	20.11
50.0%	495	20	475	495	1,962.71	1,962.71	19.73
51.0%	487	20	467	487	1,929.16	1,929.16	19.46
52.0%	479	20	459	479	1,894.74	1,894.74	19.12
53.0%	471	20	451	471	1,863.10	1,863.10	18.79
54.0%	462	20	442	462	1,824.85	1,824.85	18.44
55.0%	454	20	434	454	1,791.50	1,791.50	18.08
56.0%	450	20	430	450	1,776.58	1,776.58	17.84
57.0%	442	20	422	442	1,744.53	1,744.53	17.61
58.0%	431	20	411	431	1,696.83	1,696.83	17.21
59.0%	418	20	398	418	1,645.95	1,645.95	16.71
60.0%	413	20	393	413	1,623.75	1,623.75	16.35
61.0%	410	20	390	410	1,611.51	1,611.51	16.18
62.0%	408	20	388	408	1,603.82	1,603.82	16.08
63.0%	405	20	385	405	1,590.96	1,590.96	15.97
64.0%	404	20	384	404	1,586.83	1,586.83	15.89
65.0%	404	20	384	404	1,586.62	1,586.62	15.87
66.0%	403	20	383	403	1,582.70	1,582.70	15.85
67.0%	403	20	383	403	1,581.02	1,581.02	15.82
68.0%	402	20	382	402	1,578.57	1,578.57	15.80
69.0%	401	20	381	401	1,576.19	1,576.19	15.77
70.0%	401	20	381	401	1,574.43	1,574.43	15.75
71.0%	401	20	381	401	1,573.94	1,573.94	15.74
72.0%	400	20	380	400	1,570.58	1,570.58	15.72
73.0%	400	20	380	400	1,570.30	1,570.30	15.70
74.0%	399	20	379	399	1,566.17	1,566.17	15.68
75.0%	399	20	379	399	1,564.10	1,564.10	15.65
76.0%	398	20	378	398	1,562.06	1,562.06	15.63
77.0%	397	20	377	397	1,559.14	1,559.14	15.61
78.0%	396	20	376	396	1,553.77	1,553.77	15.56
79.0%	395	20	375	395	1,549.64	1,549.64	15.52
80.0%	394	20	374	394	1,547.54	1,547.54	15.49
81.0%	394	20	374	394	1,544.10	1,544.10	15.46
82.0%	392	20	372	392	1,536.77	1,536.77	15.40
83.0%	390	20	370	390	1,528.98	1,528.98	15.33
84.0%	387	20	367	387	1,514.68	1,514.68	15.22
85.0%	384	20	364	384	1,504.08	1,504.08	15.09
86.0%	373	20	353	373	1,459.93	1,459.93	14.82
87.0%	353	20	333	353	1,376.15	1,376.15	14.18
88.0%	331	20	311	331	1,285.66	1,285.66	13.31
89.0%	321	20	301	321	1,245.50	1,245.50	12.66
90.0%	314	20	-		-	-	6.23
91.0%	309	20	-		-	-	-
92.0%	301	20	-		-	-	-
93.0%	296	20	-		-	-	-
94.0%	291	20	-		-	-	-
95.0%	271	20	-		-	-	-
96.0%	252	20	-		-	-	-
97.0%	251	20	-		-	-	-
98.0%	250	20	-		-	-	-
99.0%	249	20	-		-	-	-
100.0%	234	20	-		-	-	-

Proposed - August - Gate No. 4 Proposed Releases							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	2,311	417	348	765	1,438.07	1,438.07	-
1.0%	1,765	417	348	765	1,438.07	1,438.07	14.38
2.0%	1,413	417	348	765	1,438.07	1,438.07	14.38
3.0%	1,353	417	348	765	1,438.07	1,438.07	14.38
4.0%	1,238	417	348	765	1,438.07	1,438.07	14.38
5.0%	1,015	417	348	765	1,438.07	1,438.07	14.38
6.0%	885	417	348	765	1,438.07	1,438.07	14.38
7.0%	849	417	348	765	1,438.07	1,438.07	14.38
8.0%	814	417	348	765	1,438.07	1,438.07	14.38
9.0%	806	417	348	765	1,438.07	1,438.07	14.38
10.0%	800	417	348	765	1,438.07	1,438.07	14.38
11.0%	798	417	348	765	1,438.07	1,438.07	14.38
12.0%	792	417	348	765	1,438.07	1,438.07	14.38
13.0%	780	417	348	765	1,438.07	1,438.07	14.38
14.0%	767	417	348	765	1,438.07	1,438.07	14.38
15.0%	761	415	346	761	1,430.12	1,430.12	14.34
16.0%	758	414	345	758	1,424.40	1,424.40	14.27
17.0%	754	411	343	754	1,416.28	1,416.28	14.20
18.0%	751	410	341	751	1,411.12	1,411.12	14.14
19.0%	719	392	327	719	1,350.82	1,350.82	13.81
20.0%	708	386	322	708	1,330.15	1,330.15	13.40
21.0%	701	383	319	701	1,317.21	1,317.21	13.24
22.0%	700	382	318	700	1,315.15	1,315.15	13.16
23.0%	699	381	318	699	1,313.17	1,313.17	13.14
24.0%	696	380	316	696	1,307.48	1,307.48	13.10
25.0%	691	377	314	691	1,298.56	1,298.56	13.03
26.0%	688	375	313	688	1,291.72	1,291.72	12.95
27.0%	683	373	311	683	1,283.10	1,283.10	12.87
28.0%	680	371	309	680	1,278.17	1,278.17	12.81
29.0%	664	362	302	664	1,248.00	1,248.00	12.63
30.0%	662	361	301	662	1,243.25	1,243.25	12.46
31.0%	656		-		-	-	6.22
32.0%	654		-		-	-	-
33.0%	652		-		-	-	-
34.0%	651		-		-	-	-
35.0%	649		-		-	-	-
36.0%	646		-		-	-	-
37.0%	617		-		-	-	-
38.0%	602		-		-	-	-
39.0%	598		-		-	-	-
40.0%	581		-		-	-	-
41.0%	580		-		-	-	-
42.0%	565		-		-	-	-
43.0%	555		-		-	-	-
44.0%	551		-		-	-	-
45.0%	540		-		-	-	-
46.0%	527		-		-	-	-
47.0%	519		-		-	-	-
48.0%	513		-		-	-	-
49.0%	500		-		-	-	-
50.0%	495		-		-	-	-
51.0%	487		-		-	-	-
52.0%	479		-		-	-	-
53.0%	471		-		-	-	-
54.0%	462		-		-	-	-
55.0%	454		-		-	-	-
56.0%	450		-		-	-	-
57.0%	442		-		-	-	-
58.0%	431		-		-	-	-
59.0%	418		-		-	-	-
60.0%	413		-		-	-	-
61.0%	410		-		-	-	-
62.0%	408		-		-	-	-
63.0%	405		-		-	-	-
64.0%	404		-		-	-	-
65.0%	404		-		-	-	-
66.0%	403		-		-	-	-
67.0%	403		-		-	-	-
68.0%	402		-		-	-	-
69.0%	401		-		-	-	-
70.0%	401		-		-	-	-
71.0%	401		-		-	-	-
72.0%	400		-		-	-	-
73.0%	400		-		-	-	-
74.0%	399		-		-	-	-
75.0%	399		-		-	-	-
76.0%	398		-		-	-	-
77.0%	397		-		-	-	-
78.0%	396		-		-	-	-
79.0%	395		-		-	-	-
80.0%	394		-		-	-	-
81.0%	394		-		-	-	-
82.0%	392		-		-	-	-
83.0%	390		-		-	-	-
84.0%	387		-		-	-	-
85.0%	384		-		-	-	-
86.0%	373		-		-	-	-
87.0%	353		-	-	-	-	-
88.0%	331		-	-	-	-	-
89.0%	321		-	-	-	-	-
90.0%	314		-	-	-	-	-
91.0%	309		-	-	-	-	-
92.0%	301		-	-	-	-	-
93.0%	296		-	-	-	-	-
94.0%	291		-	-	-	-	-
95.0%	271		-		-	-	-
96.0%	252		-		-	-	-
97.0%	251		-		-	-	-
98.0%	250		-		-	-	-
99.0%	249		-		-	-	-
100.0%	234		-		-	-	-

Existing - September -20 cfs Gate No. 4 Leakage							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	3,744	20	1,800	1,820	7,438.27	7,400.00	-
1.0%	1,497	20	1,477	1,497	6,105.33	6,105.33	67.53
2.0%	1,144	20	1,124	1,144	4,646.15	4,646.15	53.76
3.0%	931	20	911	931	3,766.37	3,766.37	42.06
4.0%	898	20	878	898	3,627.11	3,627.11	36.97
5.0%	856	20	836	856	3,453.12	3,453.12	35.40
6.0%	852	20	832	852	3,440.03	3,440.03	34.47
7.0%	818	20	798	818	3,295.80	3,295.80	33.68
8.0%	805	20	785	805	3,244.41	3,244.41	32.70
9.0%	804	20	784	804	3,240.73	3,240.73	32.43
10.0%	804	20	784	804	3,239.78	3,239.78	32.40
11.0%	800	20	780	800	3,224.95	3,224.95	32.32
12.0%	797	20	777	797	3,211.02	3,211.02	32.18
13.0%	792	20	772	792	3,190.36	3,190.36	32.01
14.0%	786	20	766	786	3,165.83	3,165.83	31.78
15.0%	782	20	762	782	3,148.30	3,148.30	31.57
16.0%	779	20	759	779	3,137.56	3,137.56	31.43
17.0%	776	20	756	776	3,124.27	3,124.27	31.31
18.0%	770	20	750	770	3,098.18	3,098.18	31.11
19.0%	762	20	742	762	3,067.22	3,067.22	30.83
20.0%	757	20	737	757	3,043.88	3,043.88	30.56
21.0%	753	20	733	753	3,030.67	3,030.67	30.37
22.0%	750	20	730	750	3,015.01	3,015.01	30.23
23.0%	745	20	725	745	2,995.64	2,995.64	30.05
24.0%	740	20	720	740	2,974.36	2,974.36	29.85
25.0%	735	20	715	735	2,953.75	2,953.75	29.64
26.0%	726	20	706	726	2,915.62	2,915.62	29.35
27.0%	724	20	704	724	2,911.07	2,911.07	29.13
28.0%	720	20	700	720	2,894.56	2,894.56	29.03
29.0%	711	20	691	711	2,854.41	2,854.41	28.74
30.0%	706	20	686	706	2,834.43	2,834.43	28.44
31.0%	704	20	684	704	2,826.54	2,826.54	28.30
32.0%	702	20	682	702	2,818.28	2,818.28	28.22
33.0%	701	20	681	701	2,812.97	2,812.97	28.16
34.0%	698	20	678	698	2,803.15	2,803.15	28.08
35.0%	697	20	677	697	2,796.29	2,796.29	28.00
36.0%	692	20	672	692	2,777.89	2,777.89	27.87
37.0%	687	20	667	687	2,754.70	2,754.70	27.66
38.0%	678	20	658	678	2,717.28	2,717.28	27.36
39.0%	662	20	642	662	2,651.34	2,651.34	26.84
40.0%	657	20	637	657	2,630.57	2,630.57	26.41
41.0%	653	20	633	653	2,614.59	2,614.59	26.23
42.0%	651	20	631	651	2,607.53	2,607.53	26.11
43.0%	648	20	628	648	2,595.13	2,595.13	26.01
44.0%	647	20	627	647	2,589.51	2,589.51	25.92
45.0%	643	20	623	643	2,575.82	2,575.82	25.83
46.0%	623	20	603	623	2,493.72	2,493.72	25.35
47.0%	616	20	596	616	2,461.02	2,461.02	24.77
48.0%	611	20	591	611	2,442.35	2,442.35	24.52
49.0%	608	20	588	608	2,429.26	2,429.26	24.36
50.0%	600	20	580	600	2,395.50	2,395.50	24.12
51.0%	597	20	577	597	2,383.19	2,383.19	23.89
52.0%	587	20	567	587	2,343.70	2,343.70	23.63
53.0%	577	20	557	577	2,300.30	2,300.30	23.22
54.0%	569	20	549	569	2,267.42	2,267.42	22.84
55.0%	557	20	537	557	2,220.04	2,220.04	22.44
56.0%	554	20	534	554	2,206.69	2,206.69	22.13
57.0%	552	20	532	552	2,199.12	2,199.12	22.03
58.0%	550	20	530	550	2,189.74	2,189.74	21.94
59.0%	542	20	522	542	2,155.98	2,155.98	21.73
60.0%	536	20	516	536	2,130.40	2,130.40	21.43
61.0%	527	20	507	527	2,096.29	2,096.29	21.13
62.0%	518	20	498	518	2,058.06	2,058.06	20.77
63.0%	511	20	491	511	2,029.26	2,029.26	20.44
64.0%	503	20	483	503	1,995.53	1,995.53	20.12
65.0%	499	20	479	499	1,979.56	1,979.56	19.88
66.0%	488	20	468	488	1,933.61	1,933.61	19.57
67.0%	470	20	450	470	1,858.49	1,858.49	18.96
68.0%	451	20	431	451	1,782.41	1,782.41	18.20
69.0%	445	20	425	445	1,756.21	1,756.21	17.69
70.0%	432	20	412	432	1,702.55	1,702.55	17.29
71.0%	427	20	407	427	1,680.00	1,680.00	16.91
72.0%	420	20	400	420	1,651.77	1,651.77	16.66
73.0%	411	20	391	411	1,615.76	1,615.76	16.34
74.0%	404	20	384	404	1,586.58	1,586.58	16.01
75.0%	399	20	379	399	1,566.90	1,566.90	15.77
76.0%	394	20	374	394	1,543.69	1,543.69	15.55
77.0%	387	20	367	387	1,516.04	1,516.04	15.30
78.0%	382	20	362	382	1,497.41	1,497.41	15.07
79.0%	364	20	344	364	1,421.90	1,421.90	14.60
80.0%	350	20	330	350	1,362.86	1,362.86	13.92
81.0%	344	20	324	344	1,338.89	1,338.89	13.51
82.0%	319	20	-		-	-	6.69
83.0%	312	20	-		-	-	-
84.0%	307	20	-		-	-	-
85.0%	299	20	-		-	-	-
86.0%	296	20	-		-	-	-
87.0%	276	20	-		-	-	-
88.0%	273	20	-		-	-	-
89.0%	272	20	-		-	-	-
90.0%	271	20	-		-	-	-
91.0%	269	20	-		-	-	-
92.0%	264	20	-		-	-	-
93.0%	251	20	-		-	-	-
94.0%	250	20	-		-	-	-
95.0%	250	20	-		-	-	-
96.0%	249	20	-		-	-	-
97.0%	248	20	-		-	-	-
98.0%	245	20	-		-	-	-
99.0%	228	20	-		-	-	-
100.0%	119	20	-		-	-	-

Proposed - September - Gate No. 4 Proposed Releases							
Percentage of Time Equaled or Exceeded	Project Outflow (cfs)	Gate No. 4 Flow (cfs)	Generation Flow (cfs)	Powerhouse + Gate No. 4 (cfs)	Predicted Power (kW)	Max Power (kW)	Power/Time
0.0%	3,744	417	348	765	1,438.07	1,438.07	-
1.0%	1,497	417	348	765	1,438.07	1,438.07	14.38
2.0%	1,144	417	348	765	1,438.07	1,438.07	14.38
3.0%	931	417	348	765	1,438.07	1,438.07	14.38
4.0%	898	417	348	765	1,438.07	1,438.07	14.38
5.0%	856	417	348	765	1,438.07	1,438.07	14.38
6.0%	852	417	348	765	1,438.07	1,438.07	14.38
7.0%	818	417	348	765	1,438.07	1,438.07	14.38
8.0%	805	417	348	765	1,438.07	1,438.07	14.38
9.0%	804	417	348	765	1,438.07	1,438.07	14.38
10.0%	804	417	348	765	1,438.07	1,438.07	14.38
11.0%	800	417	348	765	1,438.07	1,438.07	14.38
12.0%	797	417	348	765	1,438.07	1,438.07	14.38
13.0%	792	417	348	765	1,438.07	1,438.07	14.38
14.0%	786	417	348	765	1,438.07	1,438.07	14.38
15.0%	782	417	348	765	1,438.07	1,438.07	14.38
16.0%	779	417	348	765	1,438.07	1,438.07	14.38
17.0%	776	417	348	765	1,438.07	1,438.07	14.38
18.0%	770	417	348	765	1,438.07	1,438.07	14.38
19.0%	762	416	346	762	1,431.76	1,431.76	14.35
20.0%	757	413	344	757	1,421.15	1,421.15	14.26
21.0%	753	411	342	753	1,415.15	1,415.15	14.18
22.0%	750	409	341	750	1,408.02	1,408.02	14.12
23.0%	745	406	339	745	1,399.22	1,399.22	14.04
24.0%	740	404	336	740	1,389.55	1,389.55	13.94
25.0%	735	401	334	735	1,380.18	1,380.18	13.85
26.0%	726	396	330	726	1,362.85	1,362.85	13.72
27.0%	724	395	329	724	1,360.78	1,360.78	13.62
28.0%	720	393	327	720	1,353.28	1,353.28	13.57
29.0%	711	388	323	711	1,335.03	1,335.03	13.44
30.0%	706	385	321	706	1,325.94	1,325.94	13.30
31.0%	704	384	320	704	1,322.36	1,322.36	13.24
32.0%	702	383	319	702	1,318.60	1,318.60	13.20
33.0%	701	382	319	701	1,316.19	1,316.19	13.17
34.0%	698	381	317	698	1,311.73	1,311.73	13.14
35.0%	697	380	317	697	1,308.61	1,308.61	13.10
36.0%	692	378	315	692	1,300.25	1,300.25	13.04
37.0%	687	375	312	687	1,289.70	1,289.70	12.95
38.0%	678	370	308	678	1,272.70	1,272.70	12.81
39.0%	662	361	301	662	1,242.72	1,242.72	12.58
40.0%	657				-	-	6.21
41.0%	653				-	-	-
42.0%	651				-	-	-
43.0%	648				-	-	-
44.0%	647				-	-	-
45.0%	643				-	-	-
46.0%	623				-	-	-
47.0%	616				-	-	-
48.0%	611				-	-	-
49.0%	608				-	-	-
50.0%	600				-	-	-
51.0%	597				-	-	-
52.0%	587				-	-	-
53.0%	577				-	-	-
54.0%	569				-	-	-
55.0%	557				-	-	-
56.0%	554				-	-	-
57.0%	552				-	-	-
58.0%	550				-	-	-
59.0%	542				-	-	-
60.0%	536				-	-	-
61.0%	527				-	-	-
62.0%	518				-	-	-
63.0%	511				-	-	-
64.0%	503				-	-	-
65.0%	499				-	-	-
66.0%	488				-	-	-
67.0%	470				-	-	-
68.0%	451				-	-	-
69.0%	445				-	-	-
70.0%	432				-	-	-
71.0%	427				-	-	-
72.0%	420				-	-	-
73.0%	411				-	-	-
74.0%	404				-	-	-
75.0%	399				-	-	-
76.0%	394				-	-	-
77.0%	387				-	-	-
78.0%	382				-	-	-
79.0%	364				-	-	-
80.0%	350		-	-	-	-	-
81.0%	344		-	-	-	-	-
82.0%	319		-	-	-	-	-
83.0%	312		-	-	-	-	-
84.0%	307		-	-	-	-	-
85.0%	299		-	-	-	-	-
86.0%	296		-	-	-	-	-
87.0%	276		-	-	-	-	-
88.0%	273		-	-	-	-	-
89.0%	272		-	-	-	-	-
90.0%	271		-		-	-	-
91.0%	269		-		-	-	-
92.0%	264		-		-	-	-
93.0%	251		-		-	-	-
94.0%	250		-		-	-	-
95.0%	250		-		-	-	-
96.0%	249		-		-	-	-
97.0%	248		-		-	-	-
98.0%	245		-		-	-	-
99.0%	228		-		-	-	-
100.0%	119		-		-	-	-

Appendix I - Gate No. 4 Automation OPCC

Prepared by: KJC Checked: WJF

Gomez and Sullivan Engineers, D.P.C. Project No: 2179

Prepared for:

NYPA

OPINION OF PROBABLE CONSTRUCTION COST

2/1/2021

Project: **Jarvis DO Enhancement Study**

Estimate for: **Gate #4 Low Level Outlet - 60" Sluice Gate Valve Replacement/Automation**

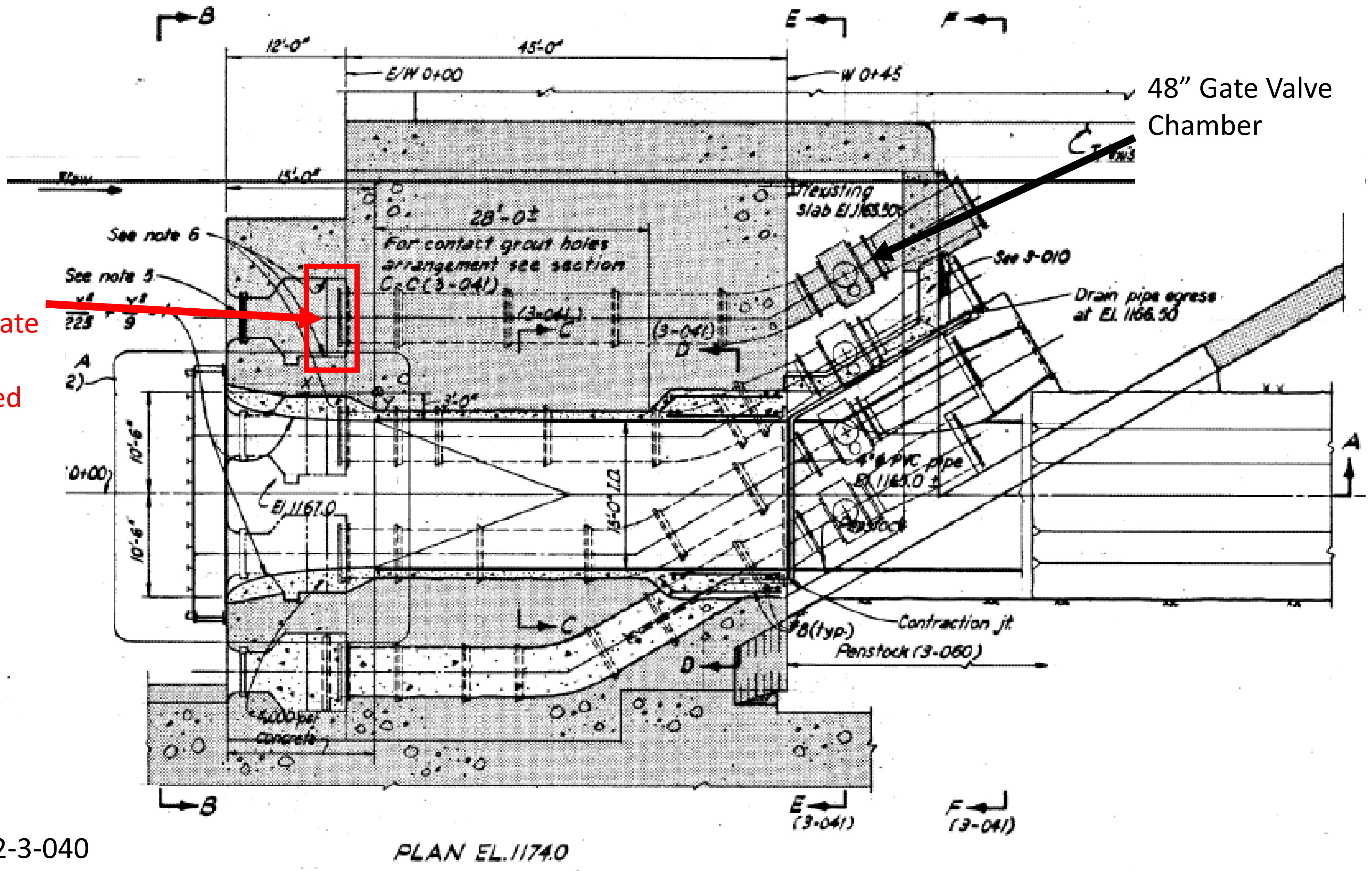
Item	Description	Quantity	Unit	Unit Price	Cost
Contractor Gen. Requirements[1] (mob/demob, on-site facilities, etc.)		10%	EA	$252,600.00	$25,260
	Selective Concrete Demolition and Disposal	1	LS	$11,000	$11,000
	Remove and Dispose of Existing 60" Sluice Gate[4] and Seal	1	LS	$6,600	$6,600
	Crane (incl. operator)	10	DAY	$3,100	$31,000
	New 60" Sluice Gate (gate only, includes delivery)[5]	1	LS	$60,000	$60,000
	New Flange/Gate Seal	1	LS	$11,000	$11,000
	Install New Gate and Gate Seal (incl. Welder, Firewatcher, EMT, 2 Divers)	5	DAY	$4,600	$23,000
	Dive Crew	5	DAY	$6,000	$30,000
	Electrical Connections/Supply	1	LS	$35,000	$35,000
	SCADA and Control System Adjustments	1	LS	$15,000	$15,000
	Tailrace Surveillance System (incl. alarm for gate opening)	1	LS	$30,000	$30,000

Subtotal Direct Cost	**$277,860**
Contingency Allowance (40%)[2]	$111,144
Total Direct Cost[3]	**$389,000**
Engineering, Administration, Permitting and Construction Management	$ 50,000
Total OPCC $2021	**$439,000**

Notes:

1. Contractor General Requirements taken as 10% of the remaining itemized costs totaled.
2. Contingency Allowance taken as 40%.
3. Rounded to the nearest $1,000.
4. Engineers OPCC is based on generally available databases (e.g. Means) and in-house pricing information for the local market. Competitive bidding environments, unknown field conditions, and other local market factors may contritbute to variances in costs.
5. It is assumed the stoplogs upstream of the valve will be installed and the downstream gate valve will be opened to dewater the conduit.
6. Costs to install and remove the stoplogs are not included.

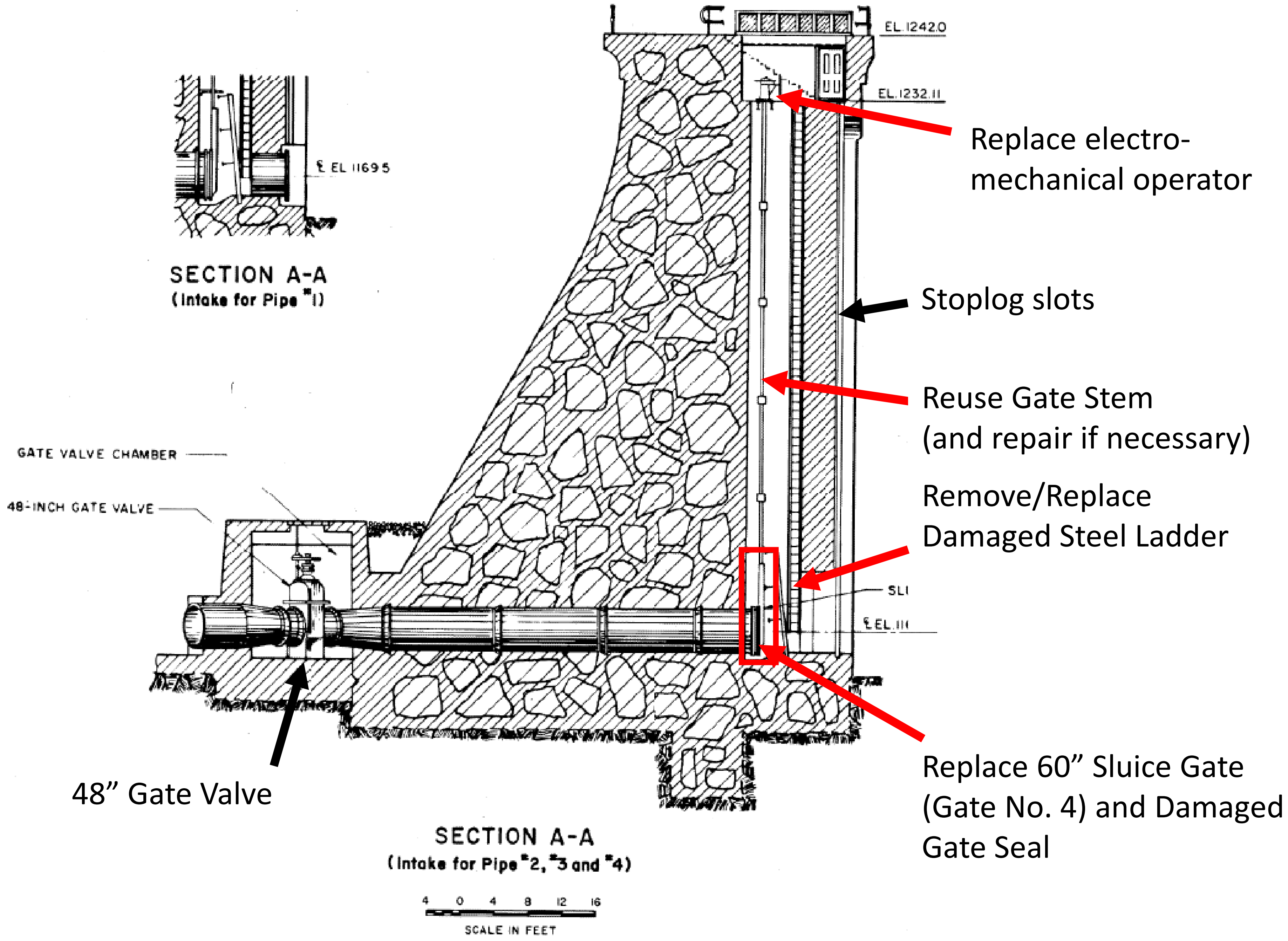
Appendix J – Gate No. 4 Automation Literature



<u>Plan View</u>

Source: 1472-3-040

Date: Jan. 20, 1984



<u>Section View</u>
Source: 1B-11
Date: Dec. 7, 1981

Appendix K – DO Monitoring Equipment Literature

FONDRIEST
ENVIRONMENTAL PRODUCTS

Bethany Belmonte
Gomez and Sullivan Engineers, P.C.
41 Liberty Hill Road
Building 1
Henniker, New Hampshire 03242
Tel. 603-428-4960

Quote: #102582
Contact: Paul Nieberding
(paul.nieberding@fondriest.com)
Date: 07/23/19
Expires: 10/21/19

Part #	Manufacturer	Description	Price	Qty	Total
		Annual Data Services			
WQData-B-Y	NexSens	WQData LIVE Basic web datacenter service, priced per year	$0.00	1	$0.00
VZ-25MB-Y	NexSens	Verizon cellular data service with 25 MB monthly allowance & static IP address, priced per year	$360.00	1	$360.00
		Subtotal			*$360.00*
		Cellular Data Buoy			
CB-50	NexSens	Data buoy with polymer-coated foam hull, 50 lb. buoyancy	$1,995.00	1	$1,995.00
X2-SDL-C-VZ4G	NexSens	X2-SDL submersible data logger with Verizon 4G LTE cellular telemetry	$2,995.00	1	$2,995.00
CAGE	NexSens	Stainless steel instrument cage, 28"	$695.00	1	$695.00
CB-CCA	NexSens	Cage anti-rotation collar for CB-Series data buoys	$295.00	1	$295.00
M550-F-Y	NexSens	Solar marine light with flange mount & 1-3 nautical mile range, 15 flashes per minute, yellow	$595.00	1	$595.00
		Subtotal			*$6,575.00*
		Dissolved Oxygen Sensor			
0088690	In-Situ	RDO PRO-X optical dissolved oxygen sensor, 10m cable	$1,598.00	1	$1,598.00
UW-CON	NexSens	UW plug connectorization of sensor cable assembly	$195.00	1	$195.00
0081300	In-Situ	RDO PRO-X anti-fouling guard	$225.00	1	$225.00
		Subtotal			*$2,018.00*

Part #	Manufacturer	Description	Price	Qty	Total
		Calibration Supplies			
0082250	In-Situ	RDO PRO-X calibration kit, includes calibration cup and 500mL Sodium Sulfite solution	$65.00	1	$65.00
0081100	In-Situ	Modbus sensor PC communication device kit, USB	$195.00	1	$195.00
UW-FL1R	NexSens	UW receptacle to flying lead cable, 1m	$100.00	1	$100.00
		Subtotal			*$360.00*

Send Purchase Order To:
Fondriest Environmental, Inc.
2091 Exchange Court
Fairborn, OH 45324
Phone: (888) 426-2151
Fax: (937) 426-1125
Email: customercare@fondriest.com

Subtotal:	$9,313.00
Tax:	$0.00
Shipping:	$99.14
Total:	$9,412.14

Delivery:	3-4 weeks ARO
Terms:	Net 30 w/ approved credit Visa, MC, AMEX, Discover
FOB Point:	Origin
Freight:	UPS - Ground

TurnKey Systems

AUTOMATED WATER QUALITY MONITORING AND TELEMETRY SYSTEMS

E123 1017

YSI

a xylem brand

TurnKey Systems

BETTER DATA. BETTER DECISIONS.

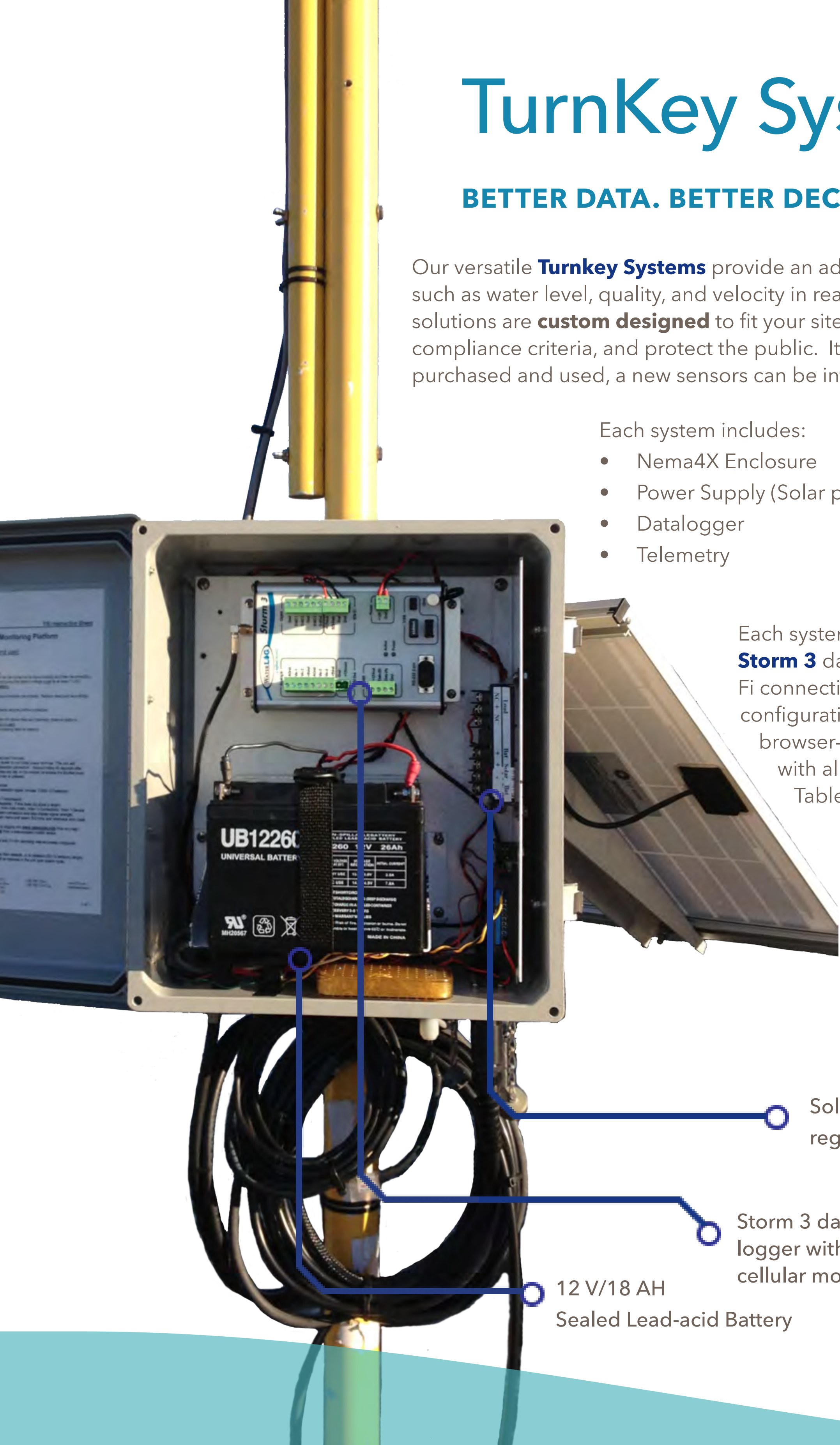
Our versatile **Turnkey Systems** provide an advanced way to measure parameters such as water level, quality, and velocity in real-time. These cost effective, complete solutions are **custom designed** to fit your site specifications, meet almost any compliance criteria, and protect the public. It is also expandable; after being purchased and used, a new sensors can be integrated into it.

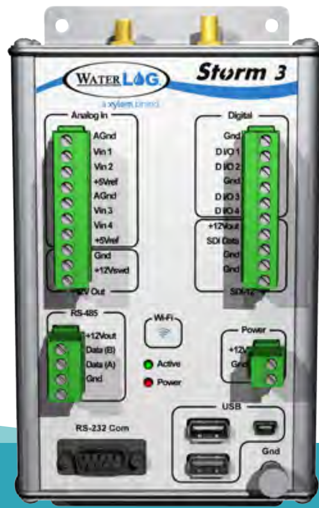
Each system includes:

- Nema4X Enclosure
- Power Supply (Solar power standard, AC option available)
- Datalogger
- Telemetry

Each system is designed around our innovative **Storm 3** data logger*. Designed with Wi-Fi connection, the Storm 3 allows easy configuration and data collection using the browser-based graphical user interface (GUI), with all standard web browsers on PCs, Tablets, and smart phones.

Real-time data collection will provide you with the versatility and access needed for proper data quality assurance and vital event trigger execution when required.





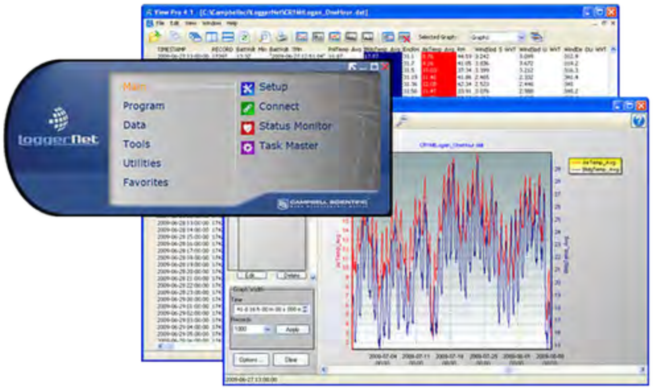
Storm 3 Data Logger

Complete solutions are custom designed to fit your site specifications

TurnKey Data Hosting Software

The YSI **Storm Central** cloud-hosted data solution collects data from the Storm data logger in real-time. Communicate through devices such as cell modems, GOES, and other transmitters. In addition, the Storm Central service is able to connect to your existing GOES stations, providing an immediate view of your data.

- View data in graphical and tabular form
- Alarm and alert system is customizable and allows remote monitoring of site
- Receive automated alerts via email, SMS text message or through color change of map icons



Programming, communication, and data retrieval between dataloggers and PC are all possible through Campbell Scientific **Loggernet**.

- View real-time data and configure your Campbell datalogger all on your PC or your iOS and Android devices.
- Create custom datalogger programs, display screens to view data
- Process data files and save data in formats that can be imported to third-party analysis packages.

ysi.com/turnkeydcp

YSI applications specialist installing a TurnKey System

Installation & Maintenance

YSI Systems Specialist are happy to assist you with installation, commissioning, and maintenance of the entire system to ensure proper function and data acquisition/transmission. We offer everything from annual checkouts and data monitoring verification to On-Site Maintenance and Management contracts to keep your data collection network running smoothly.

We know that longer intervals between maintenance and fewer failures equal significant savings in time and money. Every environment is unique. **Talk with our hands-on applications specialists**, who can assist you with your specific monitoring needs.

Trust Xylem brand sensors to provide the reliable data you need to act quickly, work efficiently and reduce costs. Our systems also have the ability to integrate third-party sensors as required, to provide a complete monitoring solution for your site.

Contact your local sales representative or visit ysi.com/systems for detailed sensor specifications, accessory options, and more.

Compatible Sensors Include:

Water Quality

Wave & Tide

Water Level

Meteorological

Precipitation

Velocity & Flow

And More!

For further information, please contact:

Website: YSI.com/turnkeydcp
Email: ysi.systems@xyleminc.com
Phone: 877-392-9950 (U.S.) or (+1) 727-565-2201