TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

INTRODUCTION

Engineer/Firm Assigned

Pursuant to a Directors Meeting held on May 17th, 2007 the Bel Marin Keys Community Services District (BMKCSD) authorized CLE Engineering, Inc. (CLE) to perform a water quality pilot study of the Paddleboat Lagoon within the South Lagoon. The study included a system install of a bottom fed aeration system, an analysis utilizing a hydrographic survey of the Paddleboat Lagoon, field analysis and laboratory sampling. Questions regarding this report, its scope and/or content should be addressed to John A. DeRugeris, P.E. or Wendy Pavao at (800) 668-3220.

This report has been prepared for the Bel Marin Keys Community Services District (BMKCSD) with the intent that it will be utilized for guiding the BMKCSD in assessing the water quality conditions in the Paddleboat Lagoon prior to the installation of the aeration system and findings of water quality after the aeration system had been installed and operational for a few months, based on the site sampling analysis performed in the field. Any other use, publication or the like of any data contained herein, by other parties without express consent of CLE Engineering is prohibited.

Background

The North and South Lagoons are two (2) manmade centrally located lagoons within the BMK Community located in Novato, CA, which are connected to the Novato Creek by navigational locks. The North Lagoon's surface area is approximately 114 acres (roughly 4,984,047 square feet), 'horse-shoe' in shape and water depths range from four to twelve feet below normal 'pool water' elevation. The South Lagoon's surface area is approximately 155 acres (roughly 6,753,390 square feet); it is irregular in shape has multiple 'sub' lagoons and fingers and water depths vary from four to thirty-five feet.

The lagoons are a valuable resource within the BMK Community. They provide water access and recreational use for residents, habitats for fish and water fowl and are an integral part of the natural systems in and around Bel Marin Keys. The lagoons are typically a stagnant water body source except for receiving water flow from flushing events from Novato Creek, groundwater re-charge, rainfall and surface water run-off from streets and yards. The water levels of the lagoons are primarily controlled by two (2) factors including precipitation and evaporation/transpiration balance, and water level management at the North and South Lock and sluice gate systems.

Reference Documents:

- Report entitled: "Bel Marin Keys Community Services District, North & South Lagoons – Water Quality Report", prepared by CLE Engineering, Inc. dated February 2007

SITE ASSESSMENT OF THE SOUTH LAGOON

It has been well documented that the South Lagoon has had a history of water quality problems, mainly stemming from undesirable algae blooms, and nuisance vegetation. A simple analysis of the South Lagoon clearly reveals that the problems being experienced are not necessarily poor horizontal circulation, but rather poor vertical circulation within the deepest area of each sub-lagoon, and that very low oxygen and stagnant water are trapped within the deep holes.

The South Lagoon has experienced water quality issues for many years. CLE prepared a water quality report prepared in 2005 and supplemented in 2007, which studied both the North and South Lagoons. The South Lagoons water quality at lower depths was found to be extremely poor and was trending in a direction where water quality over time would continue to worsen in the South Lagoon. The BMKCSD tasked CLE to study the issues of the lagoon's water and provide suitable solutions to improve the water quality in the South Lagoon. A pilot study was approved to aerate areas within a particular region in the South Lagoon (Paddleboat Lagoon) to improve water circulation and introduce oxygen into the lagoon which is one of the major issues contributing to the poor water quality. Paddleboat Lagoon provided the proper size, location, segregation and water quality issues that made it an optimal location for the pilot study. The BMKCSD authorized $25,000 for the engineering, planning, equipment purchase, installation and testing for this pilot study.

Figure 1: South Lagoon

Field Analysis

In an effort to develop an analysis of the water quality in the Paddleboat Lagoons, fifteen (15) areas were selected for water quality monitoring (See Appendix 1 for Sample Locations). CLE collected data through in-situ monitoring[1]. Field samples were tested utilizing a YSI® 650 MDS (a multi-parameter probe) in conjunction with a YSI® 6600 sonde, designed for in-situ monitoring and depth profiling. Samples were measured along three (3) levels of the water column: 6-inches from the surface, mid-depth and 6-inches from the bottom surface for the following seven (7) parameters (See Appendix 2 for a summary of Water Quality Analysis):

- Depth (ft)
- pH (measured in pH units)
- Temperature (measured in degrees Fahrenheit, F)
- Dissolved Oxygen (measured in milligrams per liter, mg/L)
- Salinity (measured in part per thousand, ppt)
- Turbidity (measured in nephelometric turbidity units, NTU)
- Specific Conductivity (measured in micro-Siemens per centimeter, µS/cm)

The multi-parameter probe utilizes sensor technology that delivers simultaneous measurements. Measurements were recorded in real-time measurements logged in an electronic data collector. The data analysis software is compatible with EcoWatch® for Windows® and was uploaded to a field computer. The equipment was calibrated as recommended by the manufacturer's specifications.

In addition, CLE collected samples along two (2) levels of the water column (6-inches from the surface and 6-inches from the bottom) at Sample Site S-7, which is centrally located within the Paddleboat Lagoon. Sampling, storage and analyses were performed according to EPA Standard Methods for the Analysis of Water and Wastewater. Samples obtained include the following:

- Alkalinity as $CaCO_3$ (mg/L)
- Ammonia as N (mg/L)
- Biochemical Oxygen Demand (mg/L)
- Carbon Dioxide, Free (mg/L)
- pH
- Phosphorus (mg/L)
- Total Dissolved Solids (mg/L)

[1] In-situ monitoring is referred to as monitoring that is performed in-place.

- Total Kjeldahl Nitrogen (mg/L)
- Nitrate as NO_3 (mg/L)
- Nitrite as NO_2 (mg/L)
- Orthophosphate (mg/L)
- Hydrogen Sulfide – Unionized (H_2S) (mg/L)
- Sulfide (S) – Total (mg/L)

Laboratory samples for the above parameters were forwarded to a certified laboratory by the State of California (Alpha Analytical Laboratories Inc. of Ukiah, CA and BSK Analytical Laboratories of Fresno, CA) to perform the water analysis testing (See Appendix 3 for a Summary of Laboratory Sampling and Appendix 4 for the Laboratory Results).

Hydrographic Survey

A hydrographic survey of the Paddleboat Lagoon was performed by CLE on April 25, 2007 to assess the water depths of the pilot study area (See Appendix 5 – Hydrographic Survey). The depths in the Paddleboat Lagoon ranged from minus 6' Mean Low Water (MLW) along the perimeter to minus 34' MLW at the center of the Paddleboat Lagoon.

Shore Power Analysis

CLE inspected the possible locations proposed for the pilot study. CLE assessed the present power distribution, voltage and phase availability for potential shore power tie-in locations that would be compatible with the proposed aeration system. The meters inspected consisted of a 240-volt, 3-wire, 60 hertz system. Two (2) potential locations existed for the Paddleboat Lagoon: Del Oro Lagoon and Dolphin Isle. The meter located on Del Oro Lagoon was removed from consideration as it was deemed to be a non cost-effective route. The tie-in location for the aeration system was selected on Dolphin Isle, meter PGE #J13632.

PILOT STUDY DESIGN

As with any ecosystem, a change in one element of the system will affect other parts of the system. Therefore, a pilot study was recommended to the BMKCSD to test the program within the South Lagoon (Paddleboat Lagoon) to determine if the dissolved oxygen distribution in the water column is more uniform after lagoon aeration/diffusion. The Paddleboat Lagoon was selected as the proposed location for the study since it was an isolated region of the overall lagoon for which CLE would be more readily able to determine the optimal benefits for the pilot study. At the May 2007 Board Meeting, CLE presented to the BMKCSD Board of Directors a comparison of aeration systems. Based upon price, product, warranty and CLE's recommendations; the Directors voted on utilizing the CLEAN-FLO system for the pilot study. CLE worked with CLEAN-FLO to relay the project goals and objectives to improve the water quality in the Paddleboat Lagoon.

CLEAN-FLO International

CLEAN-FLO International is a company based in West Chester, PA dedicated to the natural restoration of water bodies for 30 plus years. Throughout the years, CLEAN-FLO has proven their ability to improve water quality worldwide including improved water quality, reduction in weeds, algae and organic sediment, and improved fish habitat. CLEAN-FLO has designed systems to reduce algae, excessive weed growth, poor water quality, bacteria, organic sediment build up and fish kills to name a few. The CLEAN-FLO system duplicates and accelerates beneficial natural processes occurring in the water body.

The CLEAN-FLO System

Prior testing has shown that Dissolved Oxygen stratification is and has been historically problematic in the South Lagoon. Aerators have proven to break up the vertical stratification commonly found in deep water pockets within stagnant water bodies. They accomplish this by oxygenating the oxygen depleted areas within the pockets, which is a turn causes mixing with oxygen enriched surface water. The natural circulation becomes a direct solution to the low dissolved oxygen problem.

Dissolved oxygen and circulation problems are routinely improved by bottom-fed aerators. The most important part of the CLEAN-FLO solution is a process called "Continuous Laminar Flow Inversion and Oxygenation". This process oxygenates the entire water body delivering dissolved oxygen throughout the water column.

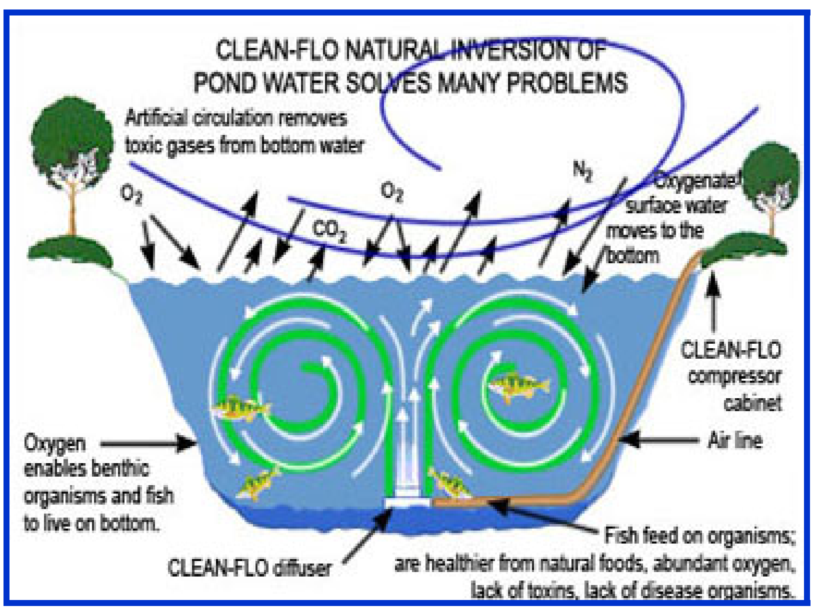

Figure 2: The CLEAN-FLO System

A typical system consists of a land based cabinet for blowers which are connected to a power system. Self-sinking air lines connect the land based cabinet along the bottom of the lagoon surface to the diffusers. Diffusers are connected to the air lines and deliver oxygen to the anoxic water trapped at deeper depths. As the oxygen is absorbed by the anoxic water it rises to the surface thereby creating a natural, vertical circulation pattern (see Figure 2). Eventually the process causes large areas of the deep water pocket to become de-stratified, as the newly enriched deeper water mixes with water of higher oxygen levels throughout the water column. Bottom fed aerators also reduce algae and increase laminar (horizontal) flow. The artificial air system is safe to recreational and boating activities as long as they are placed in deep water.

<u>*System Details*</u>

CLEAN-FLO worked with CLE Engineering to design a system that would work within the Paddleboat Lagoon of the South Lagoon. The hydrographic survey identified the most problematic deep water areas, and thus determined the most effective placement of the diffusers. The design included an inversion system with four (4) 1/3 horse-power compressors, four (4) 12-inch micro-porous ceramic diffusers and self sinking airlines to connect the diffusers. The system also included a durable fiberglass outdoor cabinet lined with sound reduction, cooling blowers and filters and was designed for 230 volt service.

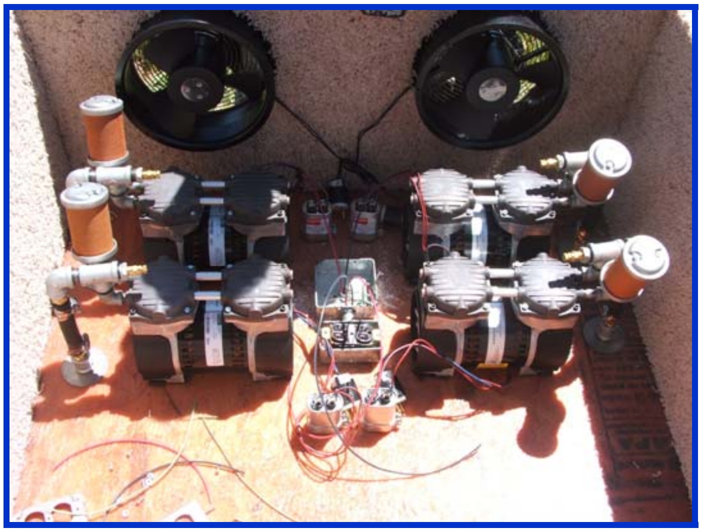

Figure 3: Compressor cabinet

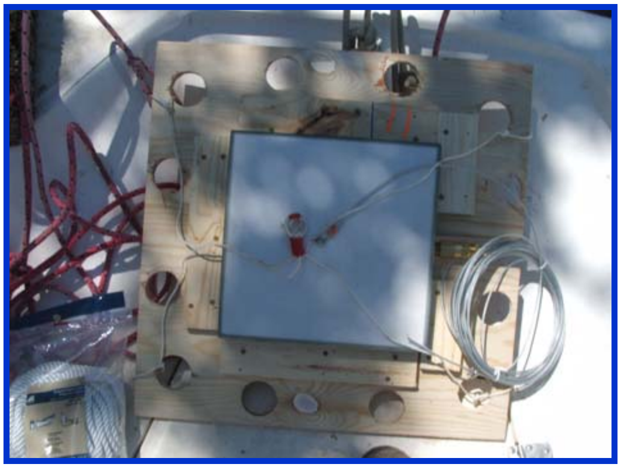

Figure 4: Micro-porous Ceramic Diffusers

The system was designed to produce high levels of oxygen throughout the water column of the lagoon. When high levels of oxygen are introduced into an oxygen deficient environment, there tends to be an increase in weed and algae growth. Beneficial bacteria and enzymes were recommended to be added to reduce the nutrients that weeds and algae need to grow. These nutrients were introduced to also address the issues accredited to organic sediment. This in turn should improve the water quality at the bottom of the water column. Without the use of nutrients, the water quality will improve using the system only; however the results will take longer. The enzymes and nutrients introduced were non-toxic and will not harm humans or the fish population.

System Install

The installation for the CLEAN-FLO Continuous Laminar Flow Inversion/Oxygenation System was completed on August 1st, 2007. The site for the placement of the cabinet was located across from the Boat Ramp on Dolphin Isle. A trench was excavated for the self-sinking airlines and electrical wiring from the cabinet to the lagoon. CLE engaged an electrician to connect the electrical service to the cabinet.

Figure 5: System Install

BACKGROUND SAMPLING

In-Situ Sampling

CLE obtained background data of the water quality for the Paddleboat Lagoon prior to the system install. Samples were monitored at Sample location S-7 for Depth (ft), pH, Temperature (°F), Dissolved Oxygen (mg/L), Salinity (ppt), Turbidity (NTU) and Specific Conductivity (μS/cm) along the top, middle and bottom levels of the water column.

pH

Most forms of aquatic life tend to be sensitive to pH levels. The pH is the measure of the acidity or how basic the water is on a scale of 0-14. Water with a pH of 7 is considered neutral, below 7 is considered "acidic" and above 7 is measured "basic". The pH is the measure of the hydrogen ions. 'It determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients; therefore metals tend to be more toxic at lower pH because they are soluble.'[2] By affecting the solubility of nutrients it can have an effect on the amount and type of nutrients available for plant growth. If there is an abundance of nutrients, aquatic plants can grow unmanageably and when they decompose they tend to lower the amount of oxygen in the water. Most natural waters will have a pH value in the range from 5.0 to 8.5. Generally pH in the range of 7 is optimum, but the acceptable level for pH is 6.8 to 8.5 (at this range carbon dioxide[3] is virtually zero).

Temperature

Water temperature is one of the most important water quality parameter since it has a direct effect on water chemistry. Water temperature influences the productivity of the ecosystem, the oxygen content of the water, density and the pH.

Dissolved Oxygen

Dissolved Oxygen (DO) is the amount of oxygen available for aquatic animals and is necessary for most forms of life. The ability for water to hold oxygen in solution is inversely proportional to the temperature of the water. With that said, the cooler the water temperature, the more dissolved oxygen it can hold. Therefore, DO concentrations are typically higher in the winter than the summer months. In addition, during rainy seasons, oxygen concentrations tend to be higher because the rain interacts with the oxygen in the air as it falls.

Dissolved oxygen is an important indicator of a water body's ability to support aquatic life. Waters with dissolved oxygen levels of less than 3.0 mg/L will not support fish or other marine life. With concentrations levels between 3.0 – 4.0 mg/L, fish migrate to the surface to breath. DO levels from 4.0 – 5.0 mg/L are tolerable to fish for short periods of

[2] Reference: Water on the Web – Understanding Water Quality Parameters: pH
[3] Carbon dioxide is a food for plants and very harmful to fish if entered into their bloodstream.

time. The minimum dissolved oxygen levels should not fall below 5.0 – 6.0 mg/L for a comfortable and healthy concentration for fish/marine life.

Salinity

Salinity is the amount of dissolved salt found in the water. Salinity in the ocean is approximately 35 parts per thousand (ppt) and San Francisco Bay has records which reveal levels at approximately 30 ppt. Water between 0.5 ppt and 17 ppt is classified as brackish water. Historical data show the North Lagoon and South Lagoon salinity levels at 17 ppt and 24 ppt respectively. The lagoons are classified as a saline body of water and become more saline due to evaporation and conversely levels of salinity drop after heavy rainfall events.

Turbidity

Turbidity indicates the concentrations of particles in the water that affect water clarity. It is the measurement of light scattered through the suspended particles, thus an increase in the amount of suspended solid particles in the water may be visually described as cloudiness.

Specific Conductivity

Specific conductivity is a measurement of the water's ability to conduct an electrical current. It is also a useful way to measure sea water intrusion into the water body. Typically, the more salt there is in the water results in a higher conductivity.

<table>
<tr><th rowspan="2">Parameter</th><th colspan="3">06/08/05</th><th colspan="3">06/23/05</th><th colspan="3">12/15/05</th><th colspan="3">06/28/07</th></tr>
<tr><th>Top</th><th>Middle</th><th>Bottom</th><th>Top</th><th>Middle</th><th>Bottom</th><th>Top</th><th>Middle</th><th>Bottom</th><th>Top</th><th>Middle.</th><th>Bottom</th></tr>
<tr><td>Depth (ft)</td><td>1.07</td><td>13.87</td><td rowspan="7">Not Sampled</td><td>1.532</td><td>15.51</td><td rowspan="7">Not Sampled</td><td>1.20</td><td rowspan="7">Not Sampled</td><td>27.03</td><td>0.6</td><td>15.2</td><td>33.82</td></tr>
<tr><td>pH</td><td>3.49</td><td>3.75</td><td>3.88</td><td>3.87</td><td>8.6</td><td>7.22</td><td>8.3</td><td>8.02</td><td>7.39</td></tr>
<tr><td>Temp (°F)</td><td>69.2</td><td>59.69</td><td>71.79</td><td>56.98</td><td>51.68</td><td>55.74</td><td>72.3</td><td>70.66</td><td>54.01</td></tr>
<tr><td>Dissolved Oxygen (mg/L)</td><td>11.17</td><td>0.41</td><td>8.42</td><td>0.75</td><td>8.38</td><td>0.17</td><td>6.49</td><td>0.86</td><td>1.13</td></tr>
<tr><td>Salinity (ppt)</td><td>17.63</td><td>24.93</td><td>18.98</td><td>25.22</td><td>22.52</td><td>23.77</td><td>21.61</td><td>21.69</td><td>24.83</td></tr>
<tr><td>Turbidity (NTU)</td><td>1.2</td><td>2.3</td><td>0.7</td><td>2.7</td><td>5.3</td><td>0.2</td><td>8.8</td><td>22.7</td><td>1.9</td></tr>
<tr><td>Spec. Cond. ((µS/cm)</td><td>28.53</td><td>39.53</td><td>30.54</td><td>39.53</td><td>35.76</td><td>37.49</td><td colspan="3">Not Sampled</td></tr>
</table>

Table 1: Background WQ Samples at S-7

In-Situ Analysis

The levels of dissolved oxygen in the South Lagoons drop consistently with depth. Since water that is high in oxygen is less dense (lighter) than water with low-oxygen, the low-oxygen water "sinks" and the high oxygen water "floats". This is why there is dramatically more oxygen at the surface of the water than at the deeper water columns due to the diffusion effect. This condition becomes more problematic over time; as the low-oxygen water accumulates at the deepest areas of a stagnant water body the water closest to the bottom, which is also where most of the decaying organic water settles. After a time the water closest to the bottom becomes even lower in DO and thus becomes even heavier, creating a layering effect. When DO levels reach the levels presently found in the South Lagoon, they become virtually impossible to de-stratify without some form of mechanical mixing device.

Laboratory Sampling

Water samples were obtained at Sample Site S-7 in the Paddleboat lagoon from laboratory analysis. Samples were collected with a submersible pump, powered by a 12-volt power supply. Samples were collected for Alkalinity as $CaCO_3$ (mg/L), Ammonia as N (mg/L), Biochemical Oxygen Demand (mg/L), Carbon Dioxide, Free (mg/L), pH, Phosphorus (mg/L), Total Dissolved Solids (mg/L), Total Kjeldahl Nitrogen (mg/L), Nitrate as NO_3 (mg/L), Nitrite as NO_2 (mg/L), Orthophosphate (mg/L), Hydrogen Sulfide – Unionized (H_2S) (mg/L) and Sulfide (S) – Total (mg/L).

Alkalinity

Alkalinity is an important characteristic of water quality as it protects against a rapid pH change in the water body. It is the sum of components including bicarbonate, carbonate and hydroxide. Acceptable ranges of alkalinity are between 20-200 mg/L.

Ammonia

Ammonia being a source of nitrogen is also a nutrient for algae and contributes to pollution within the water body. Toxic levels are both pH and temperature dependent and cause a decrease in fish reproduction and growth, or death to fish and other aquatic life. The US EPA recommends a limit of 0.025 parts per million of ammonia in marine environments.

Biochemical Oxygen Demand

BOD measures how much oxygen is utilized by organisms. This depletes the amount of dissolved oxygen available to aquatic life. Typical measurements for BOD range from 0.8 to 5.0 mg/L.

Carbon Dioxide

Carbon dioxide is present in water supplies in the form of a dissolved gas. Aquatic plant life depends upon it for growth and it is harmful for the fish's bloodstream. Typically, it is recommended that carbon dioxide levels be exhausted to protect the fish.

Phosphorous

High levels of phosphorous indicate surface runoff or detergents. Excess phosphorous in the waterway will cause algae and aquatic plants to grow uncontrollably resulting in decreasing dissolved oxygen. Algae blooms are triggered with levels of phosphorous greater than 25 micrograms per liter.

Total Dissolved Solids

Total Dissolved Solids (TDS) is measures of the amount of particulates are found in a solution. It is an indicator of pollution problems with land use practices.

Total Kjeldahl Nitrogen

TKN results from waste discharge into the water body and is the sum of organic nitrogen and ammonia.

Nitrate/Nitrites

Nitrates and Nitrites are nutrients which promote aquatic plant growth. Excessive levels can lead to algae blooms resulting in low levels of dissolved oxygen.

Orthophosphate

Orthophosphate is a measurement of the amount of phosphates found in the water. Increases in this parameter contribute to algae blooms, excessive plant growth, low concentrations of dissolved oxygen and potential deaths of marine life.

Hydrogen Sulfide

Hydrogen sulfide is affected by several parameters including pH, temperature and dissolved oxygen. Hydrogen sulfide is toxic and emits a rotten egg odor.

Parameters	6/28/2007	
	Top	Bottom
Bicarbonate Alkalinity as CaCO3(mg/L)	160	680
Carbonate Alkalinity as CaCO3 (mg/L)	ND	ND
Hydroxide Alkalinity as CaCO3 (mg/L)	ND	ND
Total Alkalinity as CaCO3 (mg/L)	160	680
Ammonia an N (mg/L)	ND	18
Biochemical Oxygen Demand (mg/L)	6.5	84
Carbon Dioxide, Free (mg/L)	ND	50
pH	8.4	7.2
Phosphorus (mg/L)	0.86	1.7
Total Dissolved Solids (mg/L)	20	24
Total Kjeldahl Nitrogen (mg/L)	1	18
Nitrate as NO3 (mg/L)	ND	ND
Nitrite as NO2 (mg/L)	ND	ND
Orthophosphate (mg/L)	Not sampled	
Hydrogen Sulfide - Unionized (H2S) (mg/L)	ND	13
Sulfide (S) - Total (mg/L)	ND	140

Table 2: Background Laboratory Samples at S-7

Laboratory Analysis

Alkalinity along the bottom of the lagoon is high and pH is unstable. BOD and carbon dioxide levels are extremely high along the bottom surface of the lagoon and most importantly, levels of hydrogen sulfide are toxic enough to kill fish and other marine life. The characteristics of the water quality along the bottom surface are poor and harmful to fish and aquatic life.

PILOT STUDY

System Start-Up

CLE completed installing four (4) ceramic diffusers in the Paddleboat Lagoon which connected to self-sinking airlines to the compressor cabinet on shore.

Figure 6: Bottom Fed Aeration (as seen from the surface)

Monitoring

CLE reviewed the water quality analysis performed for the background data. The lab results reported elevated levels of hydrogen sulfide along the bottom of the lagoon. Since the levels of hydrogen sulfide were higher than expected, the initiation of the system began with the start up of only one compressor to reduce the amount of hydrogen sulfide released. The system was initiated with the start-up of the first compressor system which switched on Friday, August 03, 2007.

Parameter	08/03/07		
	Top	Middle	Bottom
Depth (ft)	0.12	15.7	29.2
pH	7.9	7.7	7.2
Temp (°F)	76.45	72.9	54.7
Dissolved Oxygen (mg/L)	5.15	0.2	0.4
Salinity (ppt)	22.8	22.7	24.4

Table 3: In-Situ Samples (1-day after system start-up)

The second diffuser was initiated on Monday, August 06, 2007, the third on Wednesday, August 08, 2007 and the final diffuser on Thursday, August 09, 2007. This sequence was performed to minimize the amount of hydrogen sulfide ('rotten egg') odor and to protect the aquatic life. The hydrogen sulfide smell is caused from the decaying mass at the bottom of the lagoon. Without oxygen at the bottom of the lagoon, anaerobic bacteria[4] put gases in the water including hydrogen sulfide, ammonia, carbon dioxide and methane. Lack of bottom oxygen is the cause of the odors produced by anaerobic bacteria. The odor has to be released to convert the lagoon from an anaerobic condition to an aerobic (with oxygen) condition. The smell was diminished by Tuesday, August 14, 2007. There were some resident complaints regarding the odors (mostly due to an unusual wind direction experienced while the diffusers were being activated from a Southeasterly direction). CLE monitored the condition, odor and issues reported by the residents.

CLE performed another round of in-situ monitoring of the Paddleboat Lagoon:

Parameter	08/17/07		
	Top	Middle	Bottom
Depth (ft)	0.58	16	29.5
pH	8.54	8.35	8.62
Temp (°F)	76.9	73.4	54.8
Dissolved Oxygen (mg/L)	7.16	5.3	4.8
Salinity (ppt)	20.6	20.5	20.3

Table 4: In-Situ Samples (14-days after system start-up)

[4] Anaerobic bacteria is defined as bacteria that lives without oxygen.

After two-weeks from the system initiation, the dissolved oxygen levels doubled (over a 200% increase). An additional round of laboratory samples was collected on August 17th, 2007 (See Table 5). The laboratory results show a tremendous increase in the quality of the water for the Paddleboat Lagoon. BOD has stabilized throughout the water column. The results for BOD are well below the recommended levels (levels over 100 mg/L indicate organic waste). pH levels are now equal and stable and the lab results show the pH levels have been reduced at the surface and increased along the bottom of the water column. Total phosphorous is almost equal from the surface to the bottom of the water column demonstrating that the lagoon has de-stratified and the bottom levels have reduced 41%. Carbon dioxide levels have equalized and are very low. Prior to system install the carbon dioxide levels in the Paddleboat Lagoon were 50 mg/L. TKN is less at the surface and below detection levels. Bottom levels of TKN where reduced 89%. This moved bottom productivity from being phosphorous-limited to becoming nitrogen-limited, which is what the surface was prior to treatment.

Parameters	8/17/2007	
	Top	Bottom
Bicarbonate Alkalinity as CaCO3(mg/L)	160	160
Carbonate Alkalinity as CaCO3 (mg/L)	ND	ND
Hydroxide Alkalinity as CaCO3 (mg/L)	ND	ND
Total Alkalinity as CaCO3 (mg/L)	160	160
Ammonia an N(mg/L)	ND	ND
Biochemical Oxygen Demand (mg/L)	8.4	8.4
Carbon Dioxide, Free (mg/L)	3.0	3.0
pH	7.9	7.9
Phosphorus (mg/L)	0.89	0.93
Total Dissolved Solids (mg/L)	24,000	22,000
Total Kjeldahl Nitrogen (mg/L)	ND	1.9
Nitrate as NO3 (mg/L)	0.03	ND
Nitrite as NO2 (mg/L)	ND	ND
Orthophosphate (mg/L)	ND	ND
Hydrogen Sulfide - Unionized (H2S) (mg/L)	ND	ND
Sulfide (S) - Total (mg/L)	ND	ND

Table 5: Laboratory Samples (14-days after system start-up)

Beneficial bacteria and enzymes were added on Friday, August 24th, 2007 by CLE. The enzymes had some effect on the odor since they feed on the organic matter at the bottom of the lagoon. The enzymes were also added to prevent weeds and algae growth in the water while initiating the oxygen process.

After 42 days of allowing the system to run, CLE performed another round of in-situ sampling:

Parameter	09/13/07		
	Top	Middle	Bottom
Depth (ft)	0.85	15.46	29.4
pH	8.71	8.6	8.56
Temp (°F)	73	69.9	62.7
Dissolved Oxygen (mg/L)	6.8	4.5	2.12
Salinity (ppt)	21.34	21.35	21.33

Table 6: In-Situ Samples (42-days after system start-up)

The levels for dissolved oxygen dropped compared to the results obtained on August 17, 2007. This was due to the bacteria and enzymes[5] eating up the oxygen in the lagoon. According to CLEAN-FLO, a dramatic increase of the conditions of the water quality is expected during the first 2-3 weeks after installation of the Continuous Laminar Flow Inversion/Oxygenation System and the maximum improvement will be seen after six (6) months.

After 70 days from system install, CLE performed another round of in-situ sampling:

Parameter	10/11/07		
	Top	Middle	Bottom
Depth (ft)	0.59	15.7	30.8
pH	8.58	8.48	8.47
Temp (°F)	65.18	63.1	63.14
Dissolved Oxygen (mg/L)	9.57	6.28	5.91
Salinity (ppt)	24.7	24.41	24.52

Table 7: In-Situ Samples (70-days after system start-up)

The pH values are equal and stable and the dissolved oxygen levels continue to increase.

[5] Bacteria and enzymes were added to the Paddleboat Lagoon on August 24, 2007.

The water monitoring results continue to increase in quality for the Paddleboat lagoon after 84 days of the system running:

Parameter	10/25/07		
	Top	Middle	Bottom
Depth (ft)	1.51	14.2	31.14
pH	8.58	8.52	8.48
Temp (°F)	63.99	62.6	62.26
Dissolved Oxygen (mg/L)	7.95	5.98	5.05
Salinity (ppt)	24.69	24.39	24.4

Table 8: In-Situ Samples (84-days after system start-up)

CLE collected an additional round of water quality sampling to be analyzed at the laboratory.

Parameters	11/30/2007	
	Top	Bottom
Bicarbonate Alkalinity as CaCO3(mg/L)	160	160
Carbonate Alkalinity as CaCO3 (mg/L)	ND	ND
Hydroxide Alkalinity as CaCO3 (mg/L)	ND	ND
Total Alkalinity as CaCO3 (mg/L)	160	160
Ammonia an N(mg/L)	ND	ND
Biochemical Oxygen Demand (mg/L)	10	11
Carbon Dioxide, Free (mg/L)	1.5	1.5
pH	8.3	8.3
Phosphorus (mg/L)	0.34	0.35
Total Dissolved Solids (mg/L)	25,000	25,000
Total Kjeldahl Nitrogen (mg/L)	ND	ND
Nitrate as NO3 (mg/L)	35	37
Nitrite as NO2 (mg/L)	ND	ND
Orthophosphate (mg/L)	ND	ND
Hydrogen Sulfide - Unionized (H2S) (mg/L)	ND	ND
Sulfide (S) - Total (mg/L)	ND	ND

Table 9: Laboratory Samples (120-days after system start-up)

The elevated levels of Nitrogen may be influenced by the effects of rain or the natural inversion of the system which occurs naturally in all water bodies. Even though the area of study is somewhat isolated, when a natural inversion occurs the exchange of water also increases. When the results for Nitrate collected on 11/30/07 are compared to the previous sampling results, it appears the high levels of Nitrate are temporary and should stabilize. CLE recommends performing another round of sampling to verify this.

Parameter	12/06/07		
	Top	Middle	Bottom
Depth (ft)	.50	12.09	22.92
pH	9.12	9.15	9.12
Temp (°F)	53.73	53.74	53.73
Dissolved Oxygen (mg/L)	8.26	7.22	8.21
Salinity (ppt)	22.07	22.07	22.07

Table 10: In-Situ Samples (126-days after system start-up)

The dissolved oxygen levels are slightly lower that the results obtained in October. The dissolved oxygen in water is constantly changing and represents a balancing of respiration and decomposition that exhaust oxygen levels. pH levels are slightly elevated for this instance, but when compared with levels obtained on November 30, 2007 (lab reported the pH level at 8.3 units) the pH is equal and stable throughout the water column. It should be noted that samples collected December 06, 2007 were following a rainfall event which may have had an impact on the in-situ results.

What the Results Mean

The bottom fed aeration system has been running in the Paddleboat Lagoon for approximately four (4) months. Comparing the background data with the monitoring data to date, the water quality improved dramatically and the results are better than expected producing optimum levels throughout the water column.

Bacteria Results

CLE Engineering performed bacteria analysis in three (3) areas of the Paddleboat Lagoon. Coliform bacteria is an indicator of sewage and feces contamination. The EPA Water Quality standards recommend levels below 400 most probable number (MPN)/100 (See Appendix 4 for complete results).

Parameter	8/9/2007		
	Sample A	Sample B	Sample C
Total Coliform (MPN/100 ml)	22	50	80
Fecal Coliform (MPN/100 ml)	7	50	27

Table 11: Bacteria Samples

SYSTEM COSTS/MAINTENANCE

System Cost

- The system included (4)-12" ceramic diffusers, (4)-1/3 horsepower compressors and a cabinet lined with sound reduction. **Cost: $6,249.00**
- Self sinking PVC air lines: **Cost: $3,049.20**
- Beneficial bacteria and enzymes **Cost: $3,267.50**
- Bleed off valve assembly **Cost: $ 20.00**
- Freight **Cost: $ 789.80**

Total System Cost: $13,375.20

Electrical Costs

The system is designed to run on approximately 1.06 kilowatts per hour (kwh), or 765 kwh per month. That said, the cost for the electricity to run the system was estimated to be in the range of $160.00 per month. After review of the electric bill for services from 09/05/07 through 10/03/07, usage was closer to 1,200 kwh for the month and an average of 41.4 kwh per day ($228.10) and services from 10/04/07 through 10/31/07, usage was 1,158 kwh for the month and average of 41.4 kwh per day ($219.94).

Alternative Power

CLE recommends researching alternate power options including solar panels specifically for grid connectivity. Grid-tied solar electric systems are the most efficient and least costly. This would eliminate the high costs incurred for solar panels with back-up battery systems needed to ensure the system operates continuously. California also offers rebates and incentive programs for Owners who convert to solar electric systems. A cost-benefit analysis is recommended when and if the entire South Lagoon system is designed and systems installed.

Maintenance Program

Maintenance is critical to the performance of the CLEAN-FLO Continuous Laminar Flow Inversion/Oxygenation System. CLE recommends that a maintenance program be put in place for the system to perform at optimal performance levels. Every three (3) months the District should check the following in accordance to the Maintenance Instruction (See Appendix 6):

- Compressor hoses
- Compressor noises

- Pressure relief valves
- Fans

The cabinet and compressor filters should be changed every three (3) months. Compressor filters are included for the first year through CLEAN-FLO, thereafter a cost of approximately $140 per year for all four (4) compressors can be expected. This is essential for regular upkeep on the compressors and increases the longevity of the system.

In addition, the diffuser boils should be monitored frequently and periodically the diffusers should be lifted to the surface and cleaned as per manufacturer's recommendations.

Warranty/System Performance

The CLEAN-FLO system comes with a one-year warranty for the complete system and a three-year warranty for the airlines and diffusers. Failure to perform the recommended maintenance activities may void any and all warranties and will limit the results achieved by the system. The lifetime expectancy for the diffusers is estimated at over 20 years and the compressors have a 5 to 6 year lifetime based upon maintenance activities.

RECOMMENDATIONS

Monitoring Program within the South Lagoon

CLE recommends additional in-situ testing throughout the South Lagoon to develop background data. In addition, laboratory testing of areas within the South Lagoon which previously demonstrated poor water quality should be performed. The purpose of the additional testing and data would provide the BMKCSD with recommendations, implementations and estimated costs for additional aeration systems within the South Lagoon to improve its water quality. In order to move forward with additional analysis, CLE will need to perform a hydrographic survey of the South Lagoon. As previously outlined herein, deep water 'pockets' combined with a lack of circulation are leading to poor water quality within the South Lagoon. Water samples are consistently showing that fact, though are random at best. CLE does not have a full hydrographic survey of the South Lagoon. In order to properly identify these deep water 'pockets' a survey must be performed and then recommendations can be made to the BMKCSD on where possible additional systems can be added to maximize the communities' efforts. The location and placement of the aeration/diffuser systems are critical to the system success.

CONCLUSIONS

CLE has completed the pilot study within the Paddleboat Lagoon of the South Lagoon and is reporting that the study was a great success. The water quality has dramatically improved in the past three (3) months since the system was activated. Aeration can dramatically improve the aesthetics of the water quality and reduce the possibility of an algae bloom. By targeting the 'root problem' of the low level of dissolved oxygen due to stratification in the South Lagoon, the beneficial use of the waterways can continue to be a valuable source to the BMK Community.

This report has been prepared by John A. DeRugeris, P.E. and Wendy Pavao of CLE Engineering, Inc. with assistance provided by Susan E. Nilson, P.E. and P. Carey Parent. This report shall be interpreted to provide general advice and is based on engineering principals as they relate to improving the water quality in the lagoons. Questions or concerns regarding this report or the contents contained herein should be directed to CLE Engineering, Inc. at (800) 668-3220.