ASSESSMENT OF LAGOON ODOR EMISSIONS BEFORE AND AFTER INSTALLATION OF SOLAR-POWERED CIRCULATORS; MYRTLE BEACH WATER RECLAMATION FACILITY

Prepared for:

B. P. Barber & Associates
101 Research Drive
P.O. Box 1116
Columbia, SC 29203-9389

Prepared by:

BOWKER & ASSOCIATES, INC.
CONSULTING ENGINEERS
477 Congress Street, Suite 1004
Portland, ME 04101

October, 2005

EXECUTIVE SUMMARY

INTRODUCTION

The City of Myrtle Beach operates a large wastewater treatment lagoon in parallel to its mechanical treatment plant located off Mr. Joe White Avenue in Myrtle Beach, South Carolina. The lagoon system occupies an area of over 45 acres. The large, odor-emitting surface area, combined with encroaching development, has resulted in complaints against the City regarding odor emissions from the lagoons.

In June of 2004, Bowker & Associates, Inc., a firm specializing in the control of odors from waste handling facilities, was retained by B.P. Barber and Associates, Inc. (BPB) the City's wastewater consultant, to evaluate methods of mitigating odor impacts from the lagoons. A final report issued in January, 2005, recommended dredging of Cells 1, 2, and 3 and replacing the existing diffused aeration system serving these three cells with solar-powered circulators. The City installed the solar-powered circulators in January of 2005, and has attempted to pump solids from Cell 1 to reduce the volume of settled sludge. Follow-up testing was conducted in April, June, and August, 2005 to measure the lagoon odor emissions and assess whether the solar-powered circulators were achieving the desired goal of odor reduction.

DESCRIPTION OF FACILITIES

The lagoon system was designed for an average daily wastewater flow of 7 mgd. It currently treats 3 to 3.5 mgd. The lagoon water surface area is about 48 acres with a maximum depth of 14 ft. Cells 1, 2, and 3 are each approximately 7 acres; Cells 4, 5, 6, and 7 are about 5 acres; and Cell 8 is about 3 acres in size.

Cells 1, 2, and 3 are oxygenated using six SolarBee™ solar-powered circulators. The remaining cells are aerated using the existing blower/diffuser system that consists of static tube aerators anchored to the lagoon bottom. The six solar-powered circulators in Cells 1, 2, and 3 eliminated the need for about 2/3 of the 594 aerators that were supplying oxygen to the lagoon.

The lagoon is experiencing significant accumulation of wastewater solids. Cell 1 was partially dredged in early 1998, with estimated removal of 40 percent of the sludge. Despite efforts by the City to pump solids from Cell 1, it remains almost completely full of sludge.

The City had constructed a "grease holding pen" in the southeast corner of Cell 1. Grease trap waste was discharged directly into this holding pen. Due to odors from the pen and from escaping grease, the City no longer accepts grease trap waste at the plant.

The City contracted with USFilter in 2004 to provide Bioxide™ feed systems upstream in the collection system. With no chemicals, incoming sulfide levels typically average 6.5 mg/L. The target influent sulfide level with chemical addition is less then 1 mg/L.

SAMPLING PROGRAM

Bowker & Associates, Inc. conducted a sampling program at the lagoon to characterize the wastewater as well as air emissions from the lagoon surface. The following parameters were measured at selected locations in the lagoon.

Liquid

- pH
- ORP
- temperature
- total sulfide
- dissolved oxygen at 1 ft and 3 ft depths

Air

- Odor concentration (dilutions to threshold)
- Hydrogen sulfide concentration, ppm

Conditions in Cell 1 were consistently worse than the other cells with regard to odors. Prior to installation of the solar-powered circulators, odor concentration at the surface of Cell 1 was very high at 2,500 D/T, and H_2S concentration in the air above the surface was nearly 100 ppm. Virtually no dissolved oxygen was detected in the liquid and the ORP was highly negative at -143 mV. Cell 1 pH was low at 6.7, and total sulfide was measured at 2 mg/L. The character of the odor was similar to that of anaerobically digested sludge. All measured parameters clearly confirm that anaerobic digestion was occurring in this cell.

After installation of the solar-powered circulators and under stable lagoon operation, conditions in Cell 1 improved significantly. In August, 2005, atmospheric H_2S concentrations were only 2.7 ppm compared to 100 ppm, ORP was –9 mV compared to –143 mV, and total sulfide concentration in the liquid was 0.4 mg/L compared to 2 mg/L. However, odor emissions from Cell 1 remained higher than Cells 2 and 3. The presence of “sludge banks” in Cell 1 made collection of a representative sample difficult and contributed to the elevated odor emissions.

CONCLUSIONS

Based on review of collected data on lagoon conditions and odor emissions before and after installation of the solar-powered circulators, the following are the conclusions of Bowker & Associates:

1. The SolarBee™ aerators are maintaining an aerobic water cap that is minimizing odor emissions in Cells 2 and 3, and part of Cell 1.

2. The aerobic water cap is being maintained at no power cost.
3. Cell 1 is virtually filled with solids, and the "sludge banks" rise all the way to the lagoon surface in some areas.
4. Because of the high sludge blanket levels in Cell 1, achieving a uniform, aerobic water cap may be very difficult, and odor emissions from Cell 1 will continue to be higher than the remaining lagoon cells.
5. Based on the observations of Bowker & Associates, there does not appear to be a reduction of the volume of solids in Cell 1. However, it is difficult to draw any definitive conclusion because the water level in the lagoon is variable.
6. Maintaining an aerobic water cap in Cell 1 is at least partially dependent on the water level maintained in the lagoon. Lower water levels expose the sludge beds and increase odor emissions.
7. The City has prohibited the disposal of grease into the lagoon, which has eliminated one very objectionable component of the odor emissions.
8. The City has been diligent in monitoring dissolved oxygen levels in the lagoon and evaluating the effects of 1) high loadings to the lagoon during emergency or other bypasses, and 2) maintaining a minimum water surface elevation.

RECOMMENDATIONS

The following are the recommendations of Bowker & Associates to minimize odor emissions from the Myrtle Beach Water Reclamation Plant lagoon.

1. Continue using the SolarBee™ aerators in Cells 1, 2, and 3. The devices are performing better than the previous diffusers at substantially lower O&M cost.
2. Maintain routine DO monitoring program for Cells 1, 2, and 3. Such monitoring has improved the City's understanding of the impacts of higher loadings and the effect of variable water levels.
3. Continue pumping solids from Cell 1.
4. Maintain lagoon water surface elevation as high as possible in order to maximize the potential for an aerobic water cap in Cell 1
5. Remove curtain baffle between Cells 1 and 2. Evaluate whether removal of curtain allows solids in Cell 1 to dissipate into Cell 2, increasing the potential to form an aerobic water cap in Cell 1. In unsuccessful, proceed with dredging of Cell 1.

TABLE OF CONTENTS

Page No

LIST OF TABLES

Page No

1. INTRODUCTION

The City of Myrtle Beach operates a large wastewater treatment lagoon in parallel to its mechanical treatment plant located off Mr. Joe White Avenue in Myrtle Beach, South Carolina. Within the past few years, property near the facility has undergone significant commercial and residential development. A water park, restaurants, and shops have been constructed within ½ miles of the plant, and new homes are being built within 500 feet of the wastewater treatment lagoon.

The lagoon system occupies an area of over 45 acres. The large, odor-emitting surface area, combined with encroaching development, has resulted in complaints against the City regarding odor emissions from the lagoons.

In June of 2004, Bowker & Associates, Inc., a firm specializing in the control of odors from waste handling facilities, was retained by B.P. Barber and Associates, the City's wastewater consultant, to evaluate methods of mitigating odor impacts from the lagoons. A final report issued in January, 2005, recommended dredging of Cells 1, 2, and 3 and replacing the existing diffused aeration system serving these three cells with solar-powered circulators. The City installed the solar-powered circulators in January of 2005, and has attempted to pump solids from Cell 1 to reduce the volume of settled sludge. Follow-up testing was conducted in April, June, and August, 2005 to measure the lagoon odor emissions and assess whether the solar-powered circulators were achieving the desired goal of odor reduction.

2. DESCRIPTION OF FACILITIES

2.1 General

Figure 1 is a schematic diagram of the lagoon system. Raw wastewater is lifted by screw pumps into the southwest corner of Cell 1, and follows a serpentine flow path through the remaining Cells 2 – 8. The effluent is returned to the oxidation ditch activated sludge system for final treatment.

The lagoon system was designed for an average daily wastewater flow of 7 mgd. It currently treats 3 to 3.5 mgd. The lagoon system occupies approximately 48 acres with a maximum depth of 14 ft. Cells 1, 2, and 3 are each approximately 7 acres; Cells 4, 5, 6, and 7 are about 5 acres; and Cell 8 is about 3 acres in size. Design BOD and SS loadings are 11,675 lb/acre per day assuming influent BOD and SS concentration of 200 mg/L.

2.2 Aeration System

Oxygen is supplied to the lagoon using the existing blower/diffuser system for Cells 4 – 8, and using solar-powered aerators/circulators (SolarBee™) in Cells 1, 2, and 3. There are five positive displacement blowers capable of delivering a total 7,800 cfm of air with one stand-by. The design aeration rate is 5,800 cfm. There are 594 Chemineer Kenics™, vertical static tube aerators anchored to the lagoon bottom, each of which can supply 10 cfm of air, or 0.95 lb/hr of oxygen. The highest concentration of aerators is in Cells 1 and 2, each of which has about 140 aerators. Cell 3 has approximately 120 aerators, Cells 4, 5, 6, and 7 each have 40 to 50 aerators, and Cell 8 has 15. Cells 1, 2, and 3 account for 2/3 of the aerators. The diffused aerators in Cells 1, 2 and 3 are no longer in use, as they have been replaced by the solar-powered circulators. Each of Cells 1, 2, and 3 has two SolarBee™ Model SB10000v12 circulators, each capable of circulating 10,000 gal/min of water.

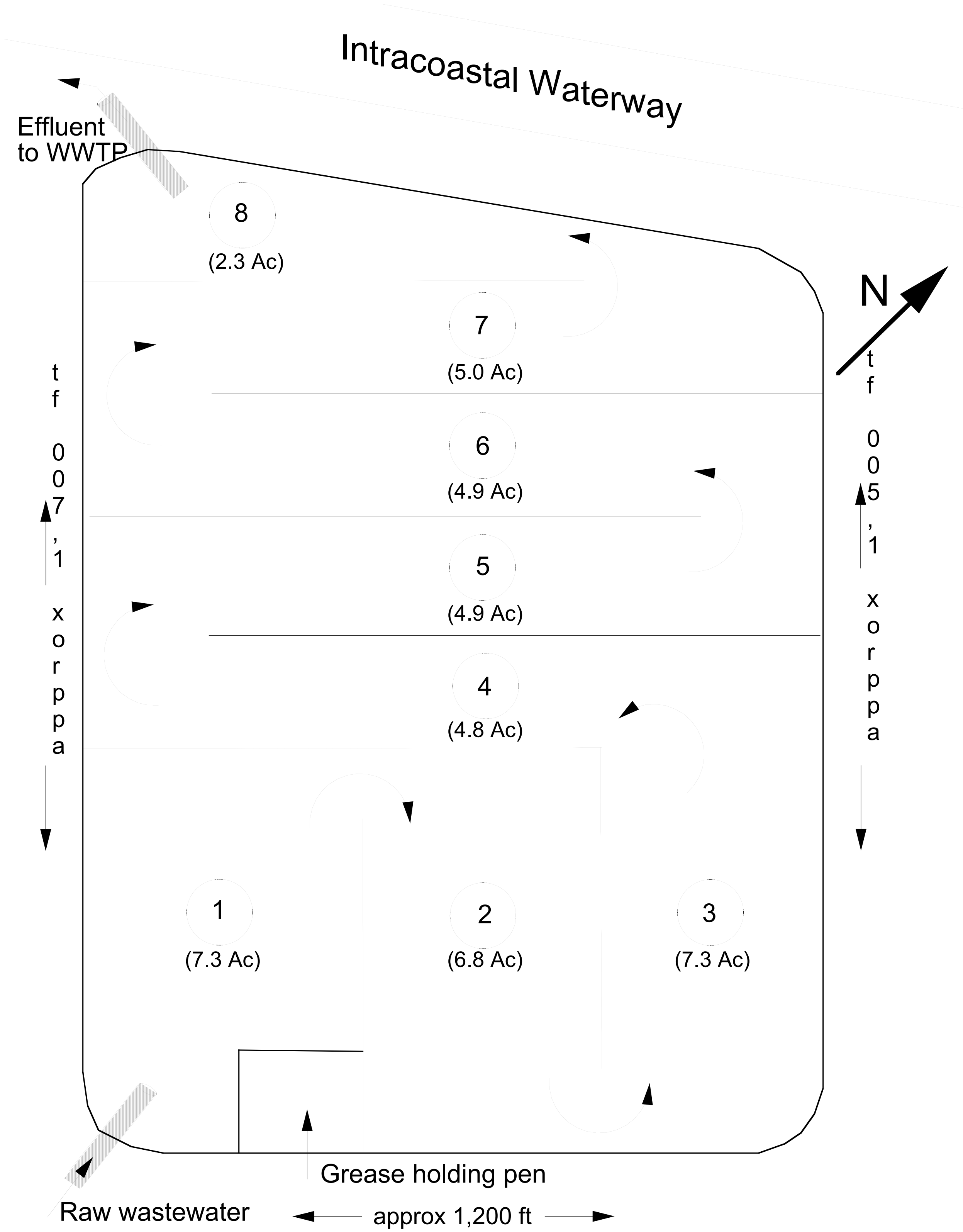

FIGURE 1. MYRTLE BEACH WASTEWATER TREATMENT LAG(
(not to scale)

2.3 Sludge Accumulation

The lagoon system is experiencing significant accumulation of wastewater solids. Cell 1 was partially dredged in early 1998, with estimated removal of 40 percent of the sludge. Since 2003, SolarBee–Pump Systems, Inc. a manufacturer of solar-powered floating aerators, has conducted measurements of sludge depths in all of the lagoon cells. In general, Cells 1, 2, and 3 are nearly full with solids, and Cell 1 has little or no "free water" above the sludge deposits. Based on measurements of sludge depths conducted by SolarBee, Inc., in 2003, B. P. Barber and Associates estimated the sludge volumes in each of the eight lagoon cells, and the cost of dredging and disposal. This analysis is shown in Table 1.

2.4 Grease Holding Pen

Until January of 2005, the City accepted grease trap pumpings, which were directed to a "grease holding pen" in the southeast corner of Cell 1. The pen is constructed of sheet piling with an aluminum cover, and air from below the cover is evacuated to a 3-stage wet scrubber system. Grease trap waste was discharged directly into this holding pen. The purpose of the holding pen was to allow enzymes or bacterial additives to be added in order to promote digestion of the grease prior to its being released to the lagoon. However, the system was only marginally effective, as grease escaped from the pen and accumulated on the surface of downstream cells. The grease was highly odorous and could be detected several hundred feet from the holding pen. As of January 14, 2005, the City no longer accepts grease trap wastes and the holding pen is not used.

2.5 Upstream Chemical Addition

The City contracted with USFilter in 2004 to provide Bioxide™ feed systems upstream in the collection system. With no chemicals, incoming sulfide levels typically average 6.5 mg/L. The target influent sulfide level with chemical addition is less then 1 mg/L.

TABLE 1 ESTIMATED SLUDGE VOLUMES AND COSTS OF DREDGING AND DISPOSAL Myrtle Beach Wastewater Lagoon[1]									
Cell No.	**Cell Area (SF)**	**Heavy Sludge (Ft)**	**Slurry Sludge (Ft)**	**Sludge Volume (CF)**	**Sludge Volume (FY)**	**Sludge Volume (Gal)**	**Land Application**	**Estimated Dry Tons**	**Landfill**
1	277,277	4.1	7.6	3,244,140.9	120,153.4	24,270,980	$1,092,194	3,036	$1,366,335
2	453,677	6.9	4.1	4,990,447.0	184,831.4	37,335,937	$1,680,117	4,671	$2,101,827
3	234,312	6.1	4.5	2,483,707.2	91,989.2	18,581,809	$836,181	2,325	$1,046,063
4	287,825	4.4	3.6	2,302,600.0	85,281.5	17,226,859	$775,209	2,155	$969,786
5	200,886	4.4	4.3	1,747,708.2	64,729.9	13,075,447	$588,395	1,636	$736,082
6	89,859	1.4	3.4	431,323.2	15,974.9	3,226,937	$145,212	404	$181,660
7	202,785	1.6	2.9	912,532.5	33,797.5	6,827,095	$307,219	854	$384,331
8	183,249	2.2	1.0	586,396.8	21,718.4	4,387,117	$197,420	549	$246,973
							$5,621,948		**$7,033,057**

NOTES:

Sludge volumes are approximate and are based on information provided by SolarBee dated July 2003.
To be conservative, land application costs are based on $0.045 per gallon. Bionomics quoted $0.035 - $0.045 per gallon.
To be conservative, landfill costs were estimated at $450 per dry ton. Bionomics quoted $350 - $450 per dry ton.
The percent solids from the lagoon was estimated to be 3% on average.
Land application of sludge from the lagoon would be dependent on meeting 503 Regulations.

[1] Prepared by B.P. Barber & Associates, Inc.

3. SAMPLING PROGRAM

3.1 Description

Bowker & Associates, Inc. conducted a series of sampling programs at the lagoon to characterize the wastewater as well as air emissions from the lagoon surface. Sampling conducted in 2005 was intended to measure the degree of odor reduction achieved with the new aeration system. The following parameters were measured at selected locations in the lagoon.

Liquid

- pH
- ORP
- temperature
- total sulfide
- dissolved oxygen at 1 ft and 3 ft depths

Air

- Odor concentration (dilutions to threshold)
- Hydrogen sulfide concentration, ppm

Liquid samples were collected at multiple locations from the surface of the lagoon. A boat was used to access the various lagoon cells. pH, ORP, and temperature were measured using a Myron L Model 4P analyzer. Total sulfide concentration was measured using a Chemetrics sulfide test kit with a range of 0.1 to 1 mg/L (by 0.1 mg/L increments) and 1 to 10 mg/L (by 1 mg/L increments). Dissolved oxygen (DO) was measured at depths of 1 ft and 3 ft using the City's YSI DO meter.

Air samples were collected from the lagoon surface using a floating, stainless steel hemispherical chamber with a bottom diameter of approximately 13 inches. The chamber was allowed to come to equilibrium, then an air sample was collected in a 10L Tedlar bag using a vacuum chamber and sampling pump. The air samples were sent by overnight carrier to St. Croix Sensory in Lake Elmo, MN for determination of odor concentration in accordance with ASTM E-679. This laboratory procedure uses an olfactometer, a device that presents known dilutions of the air sample to a panel of 8 people, to determine the strength of the odor by how many times it must be diluted with odor-free air before it can no longer be detected by half of the panel. The result is expressed in "dilutions to threshold," or D/T. Therefore, a sample with 1,000 D/T means the odorous air must be diluted 1,000 times with clean air before it is no longer detectable.

After the air sample was collected from the chamber, hydrogen sulfide concentration was measured with an Interscan Model 1176 H_2S analyzer with a range of 0.1 to 100 ppm.

3.2 Results

Table 1 summarizes the results of the sampling program from June, 2004, prior to installation of the SolarBee™ aerators. In general, Cells 3 – 8 exhibited low odor levels at the surface (60 to 75 dilutions to threshold) and little or no hydrogen sulfide. The character of the odor from these cells was a light, musty odor. Oxidation-reduction potential (ORP) was positive, indicating "oxidizing" or aerobic conditions. No sulfide was detected in the liquid.

Cell 2 appeared to be a transition cell between the highly odorous Cell 1 and the relatively non-odorous Cells 3 – 8. Although dissolved oxygen was present at the surface and ORP was positive, odor concentration was somewhat elevated at 370 D/T. H_2S in the chamber air was 0.2 ppm.

Conditions in Cell 1 were significantly worse than the other cells with regard to odors. Odor concentration was very high at 2,500 D/T, and H_2S concentration in the air was nearly 100 ppm. Virtually no DO was detected in the liquid and the ORP was highly negative at -143 mV. pH dropped to 6.7, and total sulfide was measured at 2 mg/L. The character of the odor was similar to that of anaerobically digested sludge. All measured parameters clearly confirm that anaerobic digestion was occurring in this cell.

Table 2 shows similar data collected in April, 2005, after the SolarBee™ aerators had been in service for several months. The April, 2005 results show aerobic wastewater conditions in the

TABLE 2
SUMMARY OF AIR AND LIQUID SAMPLE RESULTS
Myrtle Beach Wastewater Lagoon
June 22, 2004
Bowker & Associates, Inc.

Sample	Location	Time	------------------ Liquid ------------------						----- Air -----	
			pH, s.u.	**ORP,** mV	**Temp,** °C	**Total Sulfide** mg/L	**Dissolved Oxygen** mg/L 1 ft.	**Dissolved Oxygen** mg/L 3 ft.	**Odor Conc'n,** D/T[1]	**H_2S,** ppm
#1	Cell 8 – effluent (mid pt)	9:00 AM	6.86	+94	27.0	0.0	0.3	0.1	60	0.0
#2	Cell 5 (mid pt)	9:30 AM	7.26	+89	30.0	0.0	0.5	0.1	70	0.1
#3	Cell 3 (mid pt)	9:55 AM	7.23	+125	28.3	0.0	1.2	0.2	75	0.1
#4	Cell 2 (mid pt)	10.25 AM	7.25	+107	27.1	0.0	0.5	0.0	370	0.2
#5	Cell 1 – influent (1/3 pt)	11:00 AM	6.69	-143	29.2	2.0	0.1	0.0	2,500	98
#6	Cell 1 (end)	11:15 AM	6.80	-96	28.5	2.0	0.2	0.1	–	80
#7	Cell 2 (beginning)	11:30 AM	7.20	+106	29.0	0.0	0.3	0.1	–	1.0

1 The number of times the sample must be diluted with odor-free air before half of an 8-member panel can no longer detect the odor (ASTM E-679).

TABLE 3
SUMMARY OF AIR AND LIQUID SAMPLE RESULTS
Myrtle Beach Wastewater Lagoon
April 7, 2005
Bowker & Associates, Inc.

Sample	Location	Time	------------------ Liquid ------------------						----- Air -----	
			pH, s.u.	**ORP,** mV	**Temp,** °C	**Total Sulfide** mg/L	**Dissolved Oxygen** mg/L 1 ft.	**Dissolved Oxygen** mg/L 3 ft.	**Odor Conc'n,** D/T[1]	**H_2S,** ppm
1	Cell #3 (end)	10:00	7.02	+128	20.9	0.0	10.0	0.5	240	0.0
2	Cell #3 (mid pt)	10:20	7.04	+120	22.0	0.0	9.4	0.5	130	0.0
3	Cell #2 (end)	10:45	7.15	+100	22.6	0.0	4.8	0.3	200	<0.1
4	Cell #2 (mid pt)	11:10	7.17	+100	22.5	0.0	9.4	0.2	160	<0.1
5	Cell #1 (end)	11:40	6.81	+79	21.8	0.0	0.7	0.2	940	0.4
6	Cell #1 (mid pt)	12:30	6.64	-50	21.2	0.6	2.4	0.1	5,600	50

1 The number of times the sample must be diluted with odor-free air before half of an 8-member panel can no longer detect the odor (ASTM E-679).

Notes:

Winds SE 10 – 20 mph

Cell 1 completely full of sludge; any disturbance of surface causes black sludge to rise to surface. Maintaining boat position impossible without disturbing sludge.

top of the water column in all of Cells 2 and 3 and part of Cell 1, with positive ORP values ranging from +79 to +128 mV, positive dissolved oxygen levels ranging from 0.7 to 10.0 mg/L at 1 ft depth, and total sulfide concentrations below detection limits. Dissolved oxygen levels at the 3 ft depth were all 0.5 mg/L or less. Odor concentrations at the surface of Cells 2 and 3 were low, ranging from 130 to 240 dilutions to threshold (D/T), and H_2S concentrations were 0.0 to <0.1 ppm for Cells 2 and 3.

Cell 1 continued to be a source of odors, however. This cell appeared to be virtually full of solids. During the process of collecting samples, maintaining the position of the boat without disturbing the sludge was impossible. Any disturbance of the sludge bed increased odor and H_2S emissions. Odor and H_2S sampling was finally conducted when the boat came to rest on what appeared to be a bank of sludge near the center of Cell 1 between the two aerators.

Wastewater ORP at the midpoint of Cell 1 was -50 mV, indicating anaerobic conditions. Total dissolved sulfide was approximately 0.6 mg/L, and pH was low at 6.64, indicating that anaerobic digestion was occurring. Although a positive DO was measured at the surface, this value is not considered representative. Inside the air sampling chamber, 50 ppm of H_2S was measured. Odor concentration was a very high 5,600 D/T. Near the end of Cell 1, ORP increased to a positive value and no sulfide was detected. Atmospheric H_2S dropped from 50 ppm at the mid-point to 0.4 ppm at the end of the cell, and odor concentration decreased significantly from 5,600 to 940 D/T.

There were three factors that made comparison of June, 2004 data and the April, 2005 data difficult:

1. The samples were collected at different times of the season, and the higher wastewater temperatures in late June increase sulfide and odor generation.

2. During the April, 2005 sampling, gusty winds were encountered that increased turbulence of the lagoon surface and may have actually increased background odor emissions compared to 2004.
3. The water level in the lagoon on April 7, 2005 was approximately 8 to 10 inches lower than on June 22, 2004. This may have reduced the potential to form an aerobic water cap on Cell 1.

Bowker & Associates returned to the site in late June, 2005 to conduct a follow-up sampling under worst-case, summer conditions. Although air samples were collected, they were not analyzed because lagoon conditions were not representative. The main reason for this condition was that approximately a week before the sampling, a combination of power outages and scheduled equipment maintenance resulted in diversion of a much greater volume of wastewater through the lagoons. This caused an overloaded condition that depressed dissolved oxygen levels and temporarily increased odor emissions. The June 30, 2005 results are shown in Table 3. Several changes are apparent when comparing with previous test results:

1. All measurements in Cells 1 and 2 showed negative ORP values, indicative of anaerobic conditions.
2. All pH values were below neutral.
3. Very little dissolved oxygen was measured in any of Cells 1, 2, and 3.
4. High H_2S concentrations were measured in all of Cell 1 and much of Cell 2.

As a result of non-representative lagoon conditions, the decision was made to conduct the sampling in August after conditions in the lagoon had stabilized.

Results of sampling on August 17, 2005 are shown in Table 4. By this time, loadings to the lagoon had stabilized and the lagoon had time to fully recover. Overall, odor and H_2S emissions were lower than any of the previous testing. With the exception of the first half of Cell 1, oxidation-reduction potential (ORP) was positive, indicating oxidizing (aerobic) conditions.

Dissolved oxygen concentrations at the 1-ft depth were mostly 2.0 mg/L or above for all three cells. Only one liquid sample from the mid-point of Cell 1 showed the presence of dissolved sulfide, and at a relatively low level of 0.4 mg/L. H_2S concentrations in the headspace of the floating sampling chamber were the lowest of any of the sampling events. Only 2.7 ppm was measured at the mid-point of Cell 1, compared to concentrations near 100 ppm in all previous

TABLE 4
SUMMARY OF AIR AND LIQUID SAMPLE RESULTS
Myrtle Beach Wastewater Lagoon
June 30, 2005
Bowker & Associates, Inc.

Sample	**Location**	**Time**	------------------ **Liquid** ------------------						----- **Air** -----	
			pH, s.u.	**ORP,** mV	**Temp,** °C	**Total Sulfide** mg/L	**Dissolved Oxygen** mg/L		**Odor Conc'n,** D/T[1,2]	**H_2S,** ppm
							1 ft.	3 ft.		
1	Cell #3 (end)	9:55 AM	6.74	+83	28.4	0.0	0.6	0.2		0.1
2	Cell #3 (mid pt)	10:25 AM	6.92	+81	29.5	0.0	1.0	0.2		0.0
3	Cell #2 (end)	10:50 AM	6.95	-25	30.3	0.0	0.5	0.2		10
4	Cell #2 (mid pt)	11:15 AM	6.89	-118	30.1	0.6	0.4	0.2		52
5	Cell #1 (end)	11:35 AM	6.67	-140	31.7	2.5	0.3	0.2		>100
6	Cell #1 (mid pt)	12:50 PM	6.71	-150	32.4	2.5	0.3	0.1		>100

1 The number of times the sample must be diluted with odor-free air before half of an 8-member panel can no longer detect the odor (ASTM E-679).
2 Odor concentration not tested on June 30

TABLE 5
SUMMARY OF AIR AND LIQUID SAMPLE RESULTS
Myrtle Beach Wastewater Lagoon
August 17, 2005
Bowker & Associates, Inc.

Sample	Location	Time	------------------ Liquid ------------------						----- Air -----	
			pH, s.u.	**ORP,** mV	**Temp,** °C	**Total Sulfide** mg/L	**Dissolved Oxygen** mg/L 1 ft.	**Dissolved Oxygen** mg/L 3 ft.	**Odor Conc'n,** D/T[1]	**H_2S,** ppm
#1	Cell 3 (end)	9:30 AM	6.87	+109	30.1	0.0	1.8	0.3	200	0.0
#2	Cell 3 (mid pt)	10:00 AM	7.06	+110	30.5	0.0	2.0	0.8	230	0.0
#3	Cell 2 (end)	10:25 AM	7.05	+96	30.9	0.0	2.6	0.5	240	0.0
#4	Cell 2 (mid pt)	10:45 AM	7.06	+91	31.8	0.0	2.8	0.3	130	0.0
#5	Cell 1 (end)	11:10 AM	7.26	+77	32.6	0.0	4.5	0.5	910	0.2
#6	Cell 1 (mid pt)	11:30 AM	7.05	-9	34.9	0.4	2.0	0.8	4,200	2.7

1 The number of times the sample must be diluted with odor-free air before half of an 8-member panel can no longer detect the odor (ASTM E-679).

samplings. At the end of Cell 1, H_2S concentration in the air was down to only 0.2 ppm. Odor concentrations at the surface of Cell 1 were still elevated compared to Cells 2 and 3. However, from the mid-point to the end of Cell 1, odor concentration dropped from 4,200 to 910 D/T. Background levels in Cells 2 and 3 averaged 200 D/T.

Cell 1 remains nearly full of solids. At several locations in Cell 1, "banks" of solids were visible at the surface. This prevents formation of an aerobic water cap to help reduce odor emissions. Until a uniform water cap can be maintained, it is difficult to realize the full potential of the SolarBee™ units in minimizing odor emissions from Cell 1. However, the results of the August 17 sampling are very encouraging, and the overall emissions from the lagoon were lower than at any time during previous sampling events.

The City is considering removing the baffle curtain between Cells 1 and 2, potentially allowing the accumulated sludge to redistribute so that an aerobic water cap can be achieved without dredging of solids. However, it is not known whether this redistribution of solids will occur, and dredging of Cell 1 may still be necessary.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Based on review of collected data on lagoon conditions and odor emissions before and after installation of the solar-powered circulators, the following are the conclusions of Bowker & Associates:

1. The SolarBee™ aerators are maintaining an aerobic water cap that is minimizing odor emissions in Cells 2 and 3, and part of Cell 1.
2. The aerobic water cap is being maintained at no power cost.
3. Cell 1 is virtually filled with solids, and the "sludge banks" rise all the way to the lagoon surface in some areas.
4. Because of the high sludge blanket levels in Cell 1, achieving a uniform, aerobic water cap may be very difficult, and odor emissions from Cell 1 will continue to be higher than the remaining lagoon cells.
5. Based on the observations of Bowker & Associates, there does not appear to be a reduction of the volume of solids in Cell 1. However, it is difficult to draw any definitive conclusion because the water level in the lagoon is variable.
6. Maintaining an aerobic water cap in Cell 1 is at least partially dependent on the water level maintained in the lagoon. Lower water levels expose the sludge beds and increase odor emissions.
7. The City has prohibited the disposal of grease into the lagoon, which has eliminated one very objectionable component of the odor emissions.

8. The City has been diligent in monitoring dissolved oxygen levels in the lagoon and evaluating the effects of 1) high loadings to the lagoon during emergency or other bypasses, and 2) maintaining a minimum water surface elevation.

4.2 Recommendations

The following are the recommendations of Bowker & Associates to minimize odor emissions from the Myrtle Beach Water Reclamation Plant lagoon.

1. Continue using the SolarBee™ aerators in Cells 1, 2, and 3. The devices are performing better than the previous diffusers at substantially lower O&M cost.
2. Continue routine DO monitoring of Cells 1, 2, and 3. Such monitoring has improved the City’s understanding of the impacts of higher loadings and the effect of variable water levels.
3. Continue pumping solids from Cell 1.
4. Maintain lagoon water surface elevation as high as possible in order to maximize the potential for an aerobic water cap in Cell 1
5. Remove curtain baffle between Cells 1 and 2. Evaluate whether removal of curtain allows solids in Cell 1 to dissipate into Cell 2, increasing the potential to form an aerobic water cap in Cell 1. If unsuccessful, proceed with dredging of Cell 1.