MASSANUTTEN WATERPARK AIR QUALITY INVESTIGATION

MCGAHEYSVILLE, VIRGINIA

Letter Health Consultation

July 19, 2017

Virginia Department of Health
Division of Environmental Epidemiology
109 Governor Street
Richmond, Virginia 23219

COMMONWEALTH of VIRGINIA

DEPARTMENT OF HEALTH

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July 19, 2017

Margaret Smigo
Program Coordinator
Waterborne Hazards Control
Virginia Department of Health
109 Governor Street, 6th Floor
Richmond, VA 23218

Dear Ms. Smigo:

On February 22, 2017 you notified the Division of Environmental Epidemiology (DEE), Toxicology Program of a report that at Massanutten WaterPark the chlorine odor was so strong it caused visitors and employees to vomit. This was reported to Virginia Occupational Safety and Health (VOSH), who requested the water park management to carry out an investigation to determine if there was a hazard.

Thank you for providing us with the daily water log for this time period and the combined chlorine testing results. Subsequent to VOSH's inquiries, Massanutten WaterPark hired a contractor to do additional testing and provided these results (see enclosed report).

Based on these results we conclude that the water and air testing results do not explain the coughing and vomiting fits reported. However, many of the samples appear to have been collected during off peak hours. This could result in lower chloramine concentrations than encountered when bather load is high.

To reduce the risk of exposure to elevated chloramine and endotoxin concentrations that could potentially cause illness in staff and guests, DEE recommends:

- Consider personal air monitoring for lifeguards to measure actual chloramine exposure over the course of their shift.
- When bather load is high, close the flow rider to reduce volatilization of trichloramine.
- Clean and disinfect spas and other water features to lower endotoxin concentrations.
- Ensure ventilation is adequate to disperse and dilute chloramine and endotoxin.

BACKGROUND

Chloramine

While indoor pools are commonly described as smelling like chlorine, the odor is actually due to chloramines. Chloramines are a group of compounds including monochloramine (NH_2Cl), dicholoramine ($NHCl_2$), and trichloramine (NCl_3). In solution these compounds easily interconvert. The chloramines are volatile, with trichloramine being the most volatile and thus the chloramine typically measured in air. Monochloramine can be used to disinfect water, but is typically not used to disinfect swimming pools since it can convert to trichloroamine. Rather, chloramines in swimming pools come from the oxidation of nitrogenous compounds, primarily urea, by chlorine. Urea is a major component of urine and sweat. Because of this, chloramine concentrations are highest when bather load is high, introducing larger quantities of nitrogenous compounds into the water.

Free chlorine lowers chloramine concentrations as it converts nitrogenous compounds into trichloramine, which reacts with base and dichloramine in water to produce nitrogen gas (see Equation 1).[1] This reaction is essentially irreversible as the nitrogen leaves solution. Because of this, a potential solution for high chloramine concentrations is to shock the pool with an elevated amount of chlorine. However, this requires restricting access to the pool until free chlorine concentrations return to normal ranges.

Equation 1

$$NCl_3 + NHCl_2 + 5\ OH^- \rightarrow N_2\uparrow + 2\ OCl^- + 3\ Cl^- + 3\ H_2O$$

When trichloramine and dichloramine are present at high concentrations people breathing the air can have symptoms such as eye and nose irritation, coughing, nausea, and vomiting. Chloramines can also contribute to asthma attacks.

Air Quality Complaint

On January 23, 2017, VOSH received a complaint that the air quality in the water park was poor and that there had been an incident on the weekend of January 20-22, 2017 where a guest had vomited and was being helped by another guest and two lifeguards, who started coughing and themselves vomited.

VOSH notified the water park management, who notified the water park of the complaint and required a response to the complaint by January 31, 2017. The water park provided some water testing logs and a log of the louvers used to control intake of fresh air from outside. Additionally,

[1] Kumar K, Shinness RW, Margerum DW. Kinetics and mechanisms of the base decomposition of nitrogen trichloride in aqueous solution. *Inorg. Chem.*, **1987**, *26* (21), pp 3430–3434.

they hired Rockbridge Environmental Consulting, Inc. to do sampling to evaluate water and air quality.

Water and Air Quality

Louver Log

Louvers control intake of fresh air. The benefit of opening the louvers is greater intake of fresh air that could lower the concentration of irritants in the air. The drawback is loss of heated or cool air, increased cost for heating and cooling, and potential for bather discomfort from cold.

The louver log was provided (see Appendix A: Louver Log Sheet), but does not explicitly cover the time period of the reported incident. The log appears to only include instances upon which the louvers were opened or closed, and does not generally record their state daily. The louvers were likely open on the weekend of the incident since they were opened on January 19, 2017, and were not recorded as closed after that date. Louvers appear to be routinely left open for several days at a time.

Free Chlorine and pH

For maximum disinfectant effectiveness and swimmer comfort pH should be maintained in the 7.2–7.8 range. EPA has established a non-enforceable Maximum Residual Disinfectant Level Goal (MRDLG) of 4 mg/L for free chlorine in drinking water. EPA does not directly regulate free chlorine in swimming pools, but under the Federal Insecticide, Fungicide, and Rodenticide Act regulates labeling of chlorine sanitizers to specify 1–4 ppm free chlorine in pools and 2–5 ppm in spas, although local regulations may permit higher concentrations. CDC recommends a free chlorine concentration of 1–3 ppm in swimming pools and 2–4 ppm in spas. Virginia Administrative Code (§12VAC5-460-280) requires minimum free chlorine concentration of 0.5 ppm when bathers are present. Rockingham County does not further regulate swimming pool free chlorine concentrations.

The water park provided logs showing free chlorine for the weekend of January 20–22 and February 24, 2017. Free chlorine concentrations were within recommended ranges for all results except for one finding of 8.5 ppm free chlorine in the indoor/outdoor spa at 10:00 PM on January 21. The free chlorine had been 3.0 ppm at 8:00 PM, suggesting addition of chlorine in the interim, possibly when the pool was closing. A free chlorine log was provided for February 24 and showed elevated free chlorine of 7.2 ppm in the indoor spa at 12:00 PM.

In all logs provided pH was within the recommended range.

Oxidation-Reduction Potential

The Association of Pool and Spa Professionals recommends oxidation-reduction potential be maintained above 650 mV. In both Virginia as a whole and Rockingham County specifically swimming pool oxidation-reduction potential is not regulated. Water logs for the weekend of January 20–22 show oxidation-reduction potential was 650 mV or greater in all areas tested

except for the "kiddie pool", which had readings near 635 mV (see Appendix B: Daily Water Log). A log provided for February 24, 2017 show oxidation-reduction potential exceeding 650 mV in all areas except the "kiddie pool", which had an oxidation-reduction potential of around 600 mV (see Appendix B: Daily Water Log).

Combined Chlorine

Combined chlorine includes free chlorine, chloramines, and other chlorinated organics. Combined chlorine should be kept as low as possible, and Association of Pool and Spa Professionals recommend keeping combined chlorine at 0.2 ppm or below.

Combined chlorine test results were provided for the month of January (see Appendix C: Combined Chlorine Concentrations) and exceeded the 0.2 ppm recommendation on January 16, 2017. No test result was available for January 20, 2017 and combined chlorine concentrations were 0–0.2 ppm on January 21, 2017 and January 22, 2017.

Endotoxin Testing

Carbon monoxide, carbon dioxide, and endotoxin testing were also completed. Endotoxin is also called lipopolysaccharide and is a component of gram negative bacteria cell walls. Endotoxin is present at very low concentrations in the air of most homes with less than one endotoxin unit per cubic meter of air (EU/m^3).[2] Low exposures appear to be beneficial for infants and young children by helping to modulate immune activity and prevent atopy and asthma.[3] However, high concentrations can be harmful. Endotoxin is encountered in high concentrations during farm work. Endotoxin concentrations in swine farming have been found to reach as high as 40,000 EU/m^3.[4] While an occupational limit of 50 EU/m^3 8-hour time-weighted average was proposed in the Netherlands in 1997[5] (subsequently set at 200 EU/m^3), there is currently no OSHA personal exposure limit.

While endotoxin is generally considered for its presence in agriculture, it has also been associated with granulatomatous pneumonitis in lifeguards at indoor swimming pools ("lifeguard lung"). Rose et al. found that endotoxin concentrations as low as 28 EU/m^3 were associated with

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[2] Park JH, Spiegelman DL, Burge HA, Gold DR, Chew GL, Milton DK. Longitudinal study of dust and airborne endotoxin in the home. Environ Health Perspect. 2000 Nov;108(11):1023-8.

[3] Gehring U1, Strikwold M, Schram-Bijkerk D, Weinmayr G, Genuneit J, Nagel G, Wickens K, Siebers R, Crane J, Doekes G, Di Domenicantonio R, Nilsson L, Priftanji A, Sandin A, El-Sharif N, Strachan D, van Hage M, von Mutius E, Brunekreef B; ISAAC Phase Two Study Group. Asthma and allergic symptoms in relation to house dust endotoxin: Phase Two of the International Study on Asthma and Allergies in Childhood (ISAAC II). Clin Exp Allergy. 2008 Dec;38(12):1911-20. doi: 10.1111/j.1365-2222.2008.03087.x.

[4] O'Shaughnessy P, Peters T, Donham K, Taylor C, Altmaier R, Kelly K. Assessment of swine worker exposures to dust and endotoxin during hog load-out and power washing. Ann Occup Hyg. 2012 Aug;56(7):843-51. doi: 10.1093/annhyg/mes013. Epub 2012 Mar 16.

[5] Heederik D, Douwes J. Towards an occupational exposure limit for endotoxins. Ann Agric Environ Med 1997; 4:17-19.

an outbreak of pneumonitis among lifeguards, and that endotoxin concentrations were increased up to eight-fold by the use of water spray features at the pool studied.[6]

Endotoxin is generated in indoor swimming pools through bacteria building up in biofilms inside hoses and jets. These biofilms are resistant to standard concentrations of chlorine. Endotoxin can be suspended in the air through aerosolization of endotoxin-contaminated water. This is most likely when spray or jet water features are used.

Endotoxin is a potent activator of the innate immune system, and introduction of large doses into the bloodstream can cause septic shock. Breathing air containing elevated concentrations of endotoxin can cause cough, shortness of breath, fever, chills, headaches, and muscle and joint pain.

Endotoxin concentrations were measured in air from five areas throughout the water park on two different days (see Table 1: Endotoxin air concentrations). On the second occasion measurements from three areas exceeded 50 EU/m^3. These concentrations may be sufficient to cause symptoms in individuals who are regularly exposed.

Table 1: Endotoxin air concentrations

Location	Result (EU/m^3)		
	2/18/2017	2/20/2017	Average
First aid/top of Flowrider	47	69	58
Splash zones and slides	35	73	54
Toddler area under mezzanine	31	74	53
Locker area	25	30	28
Snack area	20	11	16

Carbon Monoxide and Carbon Dioxide

Carbon monoxide and carbon dioxide were evaluated and found to be elevated compared to background but still at safe concentrations (see the enclosed report from Rockbridge Environmental Consulting, Inc.)

DISCUSSION

It is known that exposure to indoor swimming pools contributes to respiratory symptoms in pool employees[7], professional swimmers[8], and infants under the age of two years[9]. Symptoms in

[6] Rose CS1, Martyny JW, Newman LS, Milton DK, King TE Jr, Beebe JL, McCammon JB, Hoffman RE, Kreiss K.. "Lifeguard lung": endemic granulomatous pneumonitis in an indoor swimming pool. Am J Public Health. 1998 Dec;88(12):1795-800.

swimming pool employees generally are caused by two factors, high chloramine concentrations or high endotoxin concentrations in indoor air.

The sampling data provided are not outside recommended ranges, except for excess free chlorine in spas on two occasions, modestly elevated endotoxin, and low oxidative-reductive potential in the wading pool.

Chloramine concentrations were not elevated above recommended limits on the days of testing, but the concentrations on the day of the event are unknown.

CONCLUSIONS

The water and air testing results do not explain the coughing and vomiting fits reported. However, many of the samples appear to have been collected during off peak hours. This could result in lower chloramine concentrations than encountered when bather load is high.

RECOMMENDATIONS

To reduce the risk of exposure to elevated chloramine and endotoxin concentrations that could potentially cause illness in staff and guests, DEE recommends:

- Consider personal air monitoring for lifeguards to measure actual chloramine exposure over the course of their shift.
- When bather load is high, close the flow rider to reduce volatilization of trichloramine.
- Clean and disinfect spas and other water features to lower endotoxin concentrations.
- Ensure ventilation is adequate to disperse and dilute chloramine and endotoxin.

[7] Jacobs JH, Spaan S, van Rooy GB, Meliefste C, Zaat VA, Rooyackers JM, Heederik D. Exposure to trichloramine and respiratory symptoms in indoor swimming pool workers. Eur Respir J. 2007 Apr;29(4):690-8. Epub 2006 Nov 15.

[8] Haahtela T, Malmberg P, Moreira A. Mechanisms of asthma in Olympic athletes--practical implications. Allergy. 2008 Jun;63(6):685-94. doi: 10.1111/j.1398-9995.2008.01686.x.

[9] Voisin C, Sardella A, Marcucci F, Bernard A. Infant swimming in chlorinated pools and the risks of bronchiolitis, asthma and allergy. Eur Respir J. 2010 Jul;36(1):41-7. doi: 10.1183/09031936.00118009. Epub 2010 Jan 14.

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APPENDIX A: LOUVER LOG SHEET

AHU LOUVER LOG SHEET 2017

DATE:	OPENED:	CLOSED:	REASON FOR OPEN:	INT'S.
1-1-2017	9:00AM			KL
1-1-17	1.	10:00 PM		JD
1-2 17	10:30 AM			KL
1-2-17		10:00 PM		JD
1-5-17	11:00am			KL
1-9-17		9:00 PM		JD
1-12-17	9:00AM			KL
1-16-17	9:00 AM		checked was open	KL
1-16-17		11:30 PM		JD
1-19-17	11:30 AM			KL

APPENDIX B: DAILY WATER LOG

DATE 1-20-2017

DAILY WATER LOG

TUBE LANDING

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	50,000 PF .09
KL	8:00	678	.8	7.4			665	
	10:00	669	1.0	7.4				
	12:00	662	1.2	7.5				
	2:00	673	1.5	7.4			Hand feed 22 to 20 for contamination. 22 time 3:00	

INDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	3,500 PF .03
KL	8:00	793	1.0	7.2			765	
	10:00	866	2.4	7.2				
	12:00	800	2.0	7.2				
	2:00	792	3.8	7.3				

KIDDIE POOL

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	3,500 PF .03
KL	8:00	662	1.4	7.2			635	
	10:00	644	1.0	7.2				
	12:00	642	1.6	7.4				
	2:00	650	1.2	7.4				

LAZY RIVER

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	268,000 PF 2.2
KL	8:00	649	1.0	7.2			674	
	10:00	611	1.4	7.2				
	12:00	611	1.6	7.2				
	2:00	658	2.4	7.2				

IN/OUTDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	19,200 PF .17
KL	8:00	772	3.6	7.5			760	
	10:00	761	3.2	7.4				
	12:00	823	4.0	7.4				
	2:00	777	2.0	7.4				

DATE 1/20/17

DAILY WATER LOG

TUBE LANDING

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	50,000 PF .09
GL	4:00	712	1.0	7.4			665	
	6:00	694	1.0	7.4				
	8:00	664	1.6	7.8				
	10:00	~~725~~ 725	1.0	7.4				

INDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	3,500 PF .03
GL	4:00	822	2.4	7.2			Setpoint 765	
	6:00	776	3.6	7.4				
	8:00	807	2.2	7.2				
	10:00	837	2.4	7.2				

KIDDIE POOL

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	3,500 PF .03
GL	4:00	635	2.0	7.6			635	
	6:00	638	2.2	7.6				
	8:00	635	2.2	7.6				
	10:00	635	2.0	7.6				

LAZY RIVER

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	268,000 PF 2.2
GL	4:00	707	1.0	7.2			674	
	6:00	694	1.0	7.4				
	8:00	681	1.0	7.4				
	10:00	668	1.0	7.4				

MAIN/OUTDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS	19,200 PF .17
GL	4:00	763	2.0	7.4				
	6:00	823	2.4	7.4			Setpoint 760	
	8:00	781	2.2	7.6				
	10:00	795	2.4	7.6				

DATE 1-21-2017

DAILY WATER LOG

TUBE LANDING

50,000
PF .09

NAME	TIME	ORP	CHL	PH	ALK	CAL		COMMENTS
	8:00	692	1.0	7.0			665	0
	10:00	669	1.4	7.2				
	12:00	664	1.0	7.2			670	
	2:00	692	1.0	7.2				

NDOOR SPA

3,500
PF .03

NAME	TIME	ORP	CHL	PH	ALK	CAL		COMMENTS
	8:00	942	3.0	7.0			765	.4
	10:00	800	3.0	7.2				
	12:00	824	2.2	7.2				
	2:00	757	3.8	7.2				

KIDDIE POOL

3,500
PF .03

NAME	TIME	ORP	CHL	PH	ALK	CAL		COMMENTS
	8:00	641	1.2	7.4			635	0
	10:00	637	1.4	7.4				
	12:00	637	1.6	7.4				
	2:00	634	2.6	7.4				

LAZY RIVER

268,000
PF 2.2

NAME	TIME	ORP	CHL	PH	ALK	CAL	ON OFF	COMMENTS
	8:00	747	1.6	7.0			674-675	.2
	10:00	732	1.2	7.2				
	12:00	680	1.0	7.2				
	2:00	658	1.4	7.2				

N/OUTDOOR SPA

19,200
PF .17

NAME	TIME	ORP	CHL	PH	ALK	CAL	ON OFF	COMMENTS
	8:00	779	3.0	7.4			760-761	0
	10:00	765	2.6	7.4				
	12:00	754	3.0	7.6				
	2:00	753	2.2	7.2				

DATE 1/21/17

DAILY WATER LOG

TUBE LANDING

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
[illegible]	4:00	663	1.2	7.4			670
[illegible]	6:00	617	1.0	7.4			
[illegible]	8:00	579	1.0	7.0			
[illegible]	10:00	550	1.0	7.6			

50,000
PF .09

INDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
[illegible]	4:00	817	[illegible]21	7.0			[illegible]765
[illegible]	6:00	7417	3.0	7.4			
[illegible]	8:00	765	4.4	7.2			
[illegible]	10:00	744	4.0	7.6			

3,500
PF .03

KIDDIE POOL

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
[illegible]	4:00	628	2.0	7.5			635
[illegible]	6:00	631	2.4	7.4			
[illegible]	8:00	632	3.0	7.4			
[illegible]	10:00	632	2.6	7.6			

3,500
PF .03

LAZY RIVER

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
[illegible]	4:00	699	3.[illegible]	7.0			674
[illegible]	6:00	693	2.4	7.0			
[illegible]	8:00	668	3.0	7.2			
[illegible]	10:00	708	3.[illegible]	7.4			

268,000
PF 2.2

IN/OUTDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
[illegible]	4:00	771	2.1	7.6			760
[illegible]	6:00	791	2.6	7.6			
[illegible]	8:00	762	3.0	7.6			
[illegible]	10:00	825	8.5	7.8			

19,200
PF .17

DATE 1-22-17

DAILY WATER LOG

TUBE LANDING

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	683	1.0	7.4			670
BS	10:00	668	1.4	7.4			
BS	12:00	671	1.6	7.4			
BS	2:00	671	1.4	7.4			

50,000
PF .09

INDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	829	3.0	7.2			765
BS	10:00	825	2.2	7.2			
BS	12:00	789	5.0	7.2			
BS	2:00	742	2.8	7.2			

3,500
PF .03

KIDDIE POOL

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	637	1.2	7.4			635
BS	10:00	637	1.8	7.2			
BS	12:00	634	2.4	7.4			
BS	2:00	631	2.4	7.4			

3,500
PF .03

LAZY RIVER

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	667	2.6	7.4			674, 675
BS	10:00	715	2.0	7.2			
BS	12:00	642	1.2	7.2			
BS	2:00	664	1.2	7.2			

268,000
PF 2.2

IN/OUTDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	774	2.2	7.2			760, 761
BS	10:00	784	2.6	7.2			
BS	12:00	772	3.0	7.2			
BS	2:00	764	2.4	7.2			

19,200
PF .17

vi.

DATE 1/22/17

DAILY WATER LOG

TUBE LANDING

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
M	4:00	672	1.6	7.2			50,000
adl	6:00	673	2.0	7.6			PF .09
	8:00	684	1.5	7.6			670
dl	10:00	664	2.2	7.4			

INDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
dl	4:00	765	2.2	7.4			3,500
dl	6:00	761	2.1	7.6			PF .03
dl	8:00	798	3.6	7.6			765
dl	10:00	816	2.3	7.4			

KIDDIE POOL

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
dl	4:00	630	2.2	7.6			3,500
dl	6:00	637	3.0	7.6			PF .03
dl	8:00	633	1.2	7.4			635
dl	10:00	635	1.8	7.4			

LAZY RIVER

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
dl	4:00	665	1.6	7.4			268,000
dl	6:00	672	1.6	7.6			PF 2.2
dl	8:00	680	1.2	7.4			674,675
dl	10:00	681	1.5	7.4			

IN/OUTDOOR SPA

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
dl	4:00	769	2.2	7.6			19,200
dl	6:00	759	3.0	7.8			PF .17
dl	8:00	757	2.2	7.8			760,761
dl	10:00	742	2.4	7.8			

vii

Daily Water Log

Date: 2-24-17

TUBE LANDING

50,000
PF .09

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	677	1.4	7.4			677
BS	10:00	681	1.8	7.4			
BS	12:00	694	2.4	7.4			
BS	2:00	684	1.8	7.4			

INDOOR SPA

3,500
PF .03

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	777	2.4	7.4			765
BS	10:00	805	4.0	7.4			
BS	12:00	750	7.2	7.2			
BS	2:00	759	3.6	7.2			

KIDDIE POOL

3,500
PF .03

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	600	1.8	7.2			600
BS	10:00	597	1.6	7.2			
BS	12:00	597	2.0	7.2			
BS	2:00	597	1.8	7.2			

LAZY RIVER

268,00
PF 2.2

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	779	1.6	7.2			780-781
BS	10:00	784	2.4	7.4			
BS	12:00	782	2.8	7.4			
BS	2:00	785	2.8	7.4			

IN/OUTDOOR SPA

19,200
PF .17

NAME	TIME	ORP	CHL	PH	ALK	CAL	COMMENTS
BS	8:00	805	2.6	7.4			760-761
BS	10:00	805	2.8	7.4			
BS	12:00	788	4.0	7.4			
BS	2:00	780	2.6	7.4			

ORP: Oxidation reduction potential
CHL: Free chlorine
PH: pH

APPENDIX C: COMBINED CHLORINE CONCENTRATIONS

2017 .2 8 10

Combine Chlorine Results								
	River					Indoor/Outdoor		
Date	Time	River 2	River 3	River 6	Pump Room	Body	Pump Room	Operator Int.
1-1-17	9:30AM	.2	.2	.2	.2	.2	.2	KL
1-1-17	8:00PM	.2	.2	.2	.2	.2	.2	JD/CL
1-15-17	1:00 PM	.2	.2	.2	.2	.2	.2	KL
1-15-17	10:00am	.2	.2	.0	.4	.2	.4	GL
1-16-2017	8:00AM	.4	.2	.4	.4	.2	.4	[illegible]
1-17-2017	9am	.6	.0	.2	.8	.8	.0	GL
1-21-2017	8:00AM	0	.2	.2	.2	0	0	[illegible]
1-22-2017	9:00am	0	0	.2	.2	.2	.2	BS
1-23-2017	12:30	.2	.2	.2	.2	.2	.2	KL
1-23-2017	6:00PM	.2	.2	.2	.2	.0	.2	JD/JT