An Initial Study into the Effects of Fireworks on the Water Quality of Lake George

The Lake George Association

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"Working together to protect, conserve and improve the beauty and quality of the Lake George Basin."

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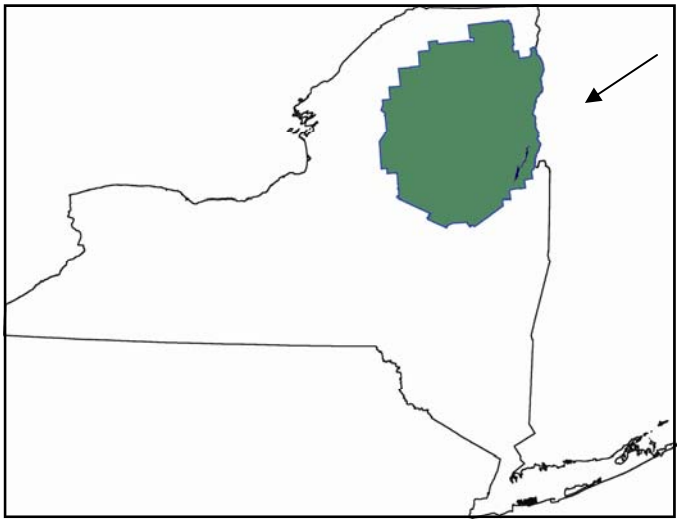
The Lake George Association (LGA) was formed in 1885. Since its inception, the LGA has evolved to incorporate and address the changing needs of the Lake George environment. The LGA advocates a reasoned, balanced approach to the management and conservation of the Lake George watershed through education, remediation, advocacy and broad-based community involvement. The goal is to ensure the long-term stability of the lake's exceptional water quality and the economic viability of the region.

Thank you to Jason Smith for collecting the water samples and to Larry Eichler of the Darrin Fresh Water Institute for his assistance in designing the study and collecting the sediment samples. Thank you also to the members of the LGA's Water Quality Committee, especially Bob Metivier, for their assistance with this project. Thank you to Eric Paparatto and Pete Greer for sharing their photographs of fireworks over Lake George. This report was compiled by LGA staff members Emily DeBolt, Kristen Rohne, and Jason Smith.

Cover Photo of fireworks on Lake George by Eric Paparatto.

Introduction



Lake George is a 32 mile long graben/ glacial lake situated in the southeast corner of the Adirondack Park in New York State. The maximum depth is just under 200 ft, while the lake averages a depth of 70 ft. The lake's surface area is 45 square miles at an elevation of 320 ft. Lake George is rated as a Class AA-Special surface water by the State of New York, meaning its best usages is a source of water supply for drinking, culinary or food processing purposes, primary and secondary recreation, and fishing. However, Lake George has also been listed on the New York State 303 (d) List of Impaired Waters. Both the lake itself and the tributaries feeding into the lake are being polluted by silt and sediment from stormwater runoff due to development and erosion. Aquatic invasive species also threaten the lake. Chemical contaminants generally are not as large of a water quality concern for the lake as stormwater runoff and aquatic invasive species, however in recent years as the number of fireworks displays has gone up, concern has been voiced over the consequences of these shows.

Throughout the months of July and August the Village of Lake George sponsors fireworks displays, mainly on Thursday nights. The displays are set off from a barge that remains within several hundred meters of the shore in close proximity to Lake George Village. Since the Village of Lake George draws its municipal water from Lake George, there is concern that the weekly Thursday night fireworks display could have a potential impact on the water supply. Besides municipal water systems, some residential homes from around the lake get their drinking water piped in directly from the lake as well. While most of the fireworks occur near Lake George Village, that is not the only place on the lake where there are displays during the summer. In addition to the Village sponsored fireworks, there are a number of other fireworks displays on the lake as well. Private homes sometimes have displays, hotels such as The Sagamore Hotel have displays, as well as other municipalities such as the Towns of Bolton and Hague. Since there is no required permit to have a fireworks display on Lake George, the exact number and location of these shows each summer is unknown.

Discussion about the effects of fireworks on Lake George is not new. It has come up at Village Planning Board and Lake George Park Commission Board meetings in years past. In 2008, due to a number of shows right in a row, interest in the matter arose again, a bit louder this time. Bill Dow, owner of the Lake George Steamboat Company, said that his barge was used for 11 Village shows, along with some other contracted shoots, for a total of 21 shows in 2008. So we know how many shows are done on the Steamboat Company's barge, but there are shows that do not use the barge, so we have no way of knowing the total number of shows for the season.

As a result of the increased interest in the issue, the LGA hosted a meeting in October of 2008 to discuss the matter with a number of local officials. LGA staff then followed up with a meeting with Jeff Alonzo, owner of Alonzo Fireworks, the company hired by lake George Village and for most other shows done on the lake. However, we still did not know if there was really cause for concern or not, since no testing of water quality parameters related to fireworks has been done on Lake George to date. So we decided to follow up with our own initial investigation into the effects of fireworks on Lake George.

In more recent years, with increasing interest in new age contaminants, there have been a few studies on perchlorate, which is used as a propellant in fireworks. While most of it combusts, all of it does not, resulting in perchlorate falling down on the land and water. There are health and environmental concerns associated with perchlorate contamination, many of which are still not well understood. Perchlorate is absorbed by the thyroid gland in place of iodine, which can interfere with the production of thyroid hormone, which is essential to metabolism and mental development.

There is no federal or NYS drinking water standard for perchlorate. The US EPA does have a Drinking Water Equivalent value of 24.5 ppb, but that is an intermediate value used to set a final standard and is not an actual standard. In 2006 Massachusetts was the first state to set such a standard, and set the drinking water standard for perchlorate at 0.002mg/L. Part of the problem is that there is not really much agreement on what is or is not a safe amount of perchlorate. But for the purposes of our study we used 0.002 mg/L as a reference point. This reference is much lower than the EPA value, so we used it to be as conservative as possible.

Background on Fireworks Contaminants


Photo by Pete Greer

Throughout a fireworks display there are several short term, and predictable, impacts on the environment. Examples include the elevated noise levels, accumulation of debris, and smoke suspended in the air surrounding the display. There is however concern over the long term, and less obvious, effects a fireworks display can have on the environment.

Perchlorate (ClO_4^-) originates from the dissolution of salts such as ammonium, sodium, potassium, and magnesium in water. In these forms perchlorate is used as an oxidizer in propellants for pyrotechnics. Perchlorate is recognized as a contaminant; however the full implications of elevated perchlorate levels in an aquatic system are not yet fully understood. Elevated perchlorate levels have been linked to hypertrophy and colloid depletion in fish. Perchlorate also has health implications for humans. It is absorbed by the thyroid gland in place of iodine, which can interfere with the production of thyroid hormone. Thyroid hormone is essential to metabolism and mental development, so perchlorate exposure is thought to be particularly harmful to fetuses. The potential impact of perchlorate on humans and other living organisms is directly linked to its mobility and attenuation in the environment. Other studies have found that the availability of organic carbon to provide energy for perchlorate reducing bacteria may be a key factor in determining attenuation rates of perchlorate in the environment, but more study is needed.

While most of the perchlorate in fireworks combusts, any that does not falls down on the nearby land or water. In aquatic systems, perchlorate has not been extensively studied; therefore there is uncertainty in the relationship between the environmental presence of perchlorate and fireworks displays.

Antimony (Sb) and Barium (Ba) are two common chemical components of fireworks. Antimony is a metal used to create firework glitter effects. Barium is used to create green colors in fireworks. It is also used to stabilize other volatile elements of the fireworks. At increased concentrations, antimony has been shown to cause heart problems and stomach ulcers in humans. In small mammals, antimony has been shown to cause lung, heart, liver and kidney damage and eventually death. Water soluble forms of barium have been linked to increased blood pressure, kidney and heart damage, and breathing difficulties in humans. Barium also bioaccumulates in fish and other aquatic organisms.

The following chart shows common fireworks ingredients, what they are used for, and why they are dangerous. This chart is from the Environmental Fact Sheet "Fireworks and New Hampshire's Lakes" produced by the New Hampshire Department of Environmental Services in 2008. The full document can be found online at http://des.nh.gov/organization/commissioner/pip/factsheets/bb/documents/bb-60.pdf

Toxic Element	Fireworks Usage	Toxic Effect of Fallout Dust & Fumes
Lead Nitrate/Dioxide/Chloride	oxidizer	Bioaccumulation; developmental danger for children and the unborn; may remain airborne for days; poisonous to plants and animals
Barium	glittering greens	Extremely poisonous, radioactive
Lithium	blazing reds	Slightly toxic
Rubidium	purple colors	Slightly radioactive; can replace calcium in body
Strontium	blazing reds	Can replace calcium in body; can be radioactive
Copper compounds	blues	Dioxin pollution
Aluminum	brilliant whites	Contact dermatitis
Ammonium Perchlorate	propellant	Can contaminate ground and surface waters; can disrupt thyroid functions
Cadmium	firework colors	Extremely toxic, carcinogenic; can bioaccumulate
Potassium Nitrate	in black powder	Toxic dusts, carcinogenic sulfur-coal compounds
Sulfur Dioxide	gaseous byproduct of sulfur combustion	Acid rain from sulphuric acid affects water sources, vegetation and causes property damage

Photo by Pete Greer

Methods

Sample Collection. Surface water samples were collected at three locations, Site 1, Site 2 and Site 3 (Figure 1), in close proximity to Lake George Village where the fireworks barge launches the display. The sampling took place one week in June before any 2009 fireworks displays occurred to develop a baseline of background levels, and then throughout the month of July. Samples were collected the day before a scheduled display, and then the morning after the display and again 24 hours after that. Fireworks were often on Thursday nights throughout July so samples were taken at 8:00am on Wednesday, Friday and Saturday. Weeks when fireworks displays took place on another day the sampling dates were adjusted. Two samples were collected at each site, one for perchlorate and one for antimony and barium. The samples were collected using a Kemmerer Bottle at a depth of 0.5m. The Kemmerer Bottle was washed with water from the sample site. Once the sample was collected the sample was put into plastic bottles provided by M.J. Reider Associates, Inc, the lab used for analysis. The Antimony-Barium samples were preserved with Nitric Acid (HNO_3), and the perchlorate samples as well as the Antimony-Barium samples were kept refrigerated at 4°C until analysis. Other field measurements included latitude/longitude with a handheld GPS receiver, pH, depth, and temperature.

Sediment samples were collected at the same three locations as the surface water samples as well as in 3 locations near Shelving Rock (Figure 2). The sediment sampling took place on October 7, 2009. One sample was collected at each of the 6 sites using divers and sediment corers. Samples were then bagged and shipped to M.J. Reider Associates, Inc for perchlorate analysis.

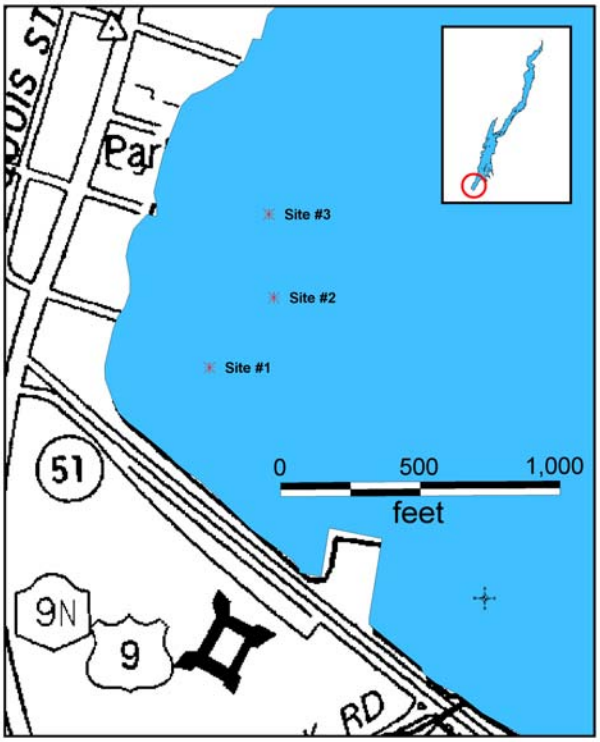


Figure 1.

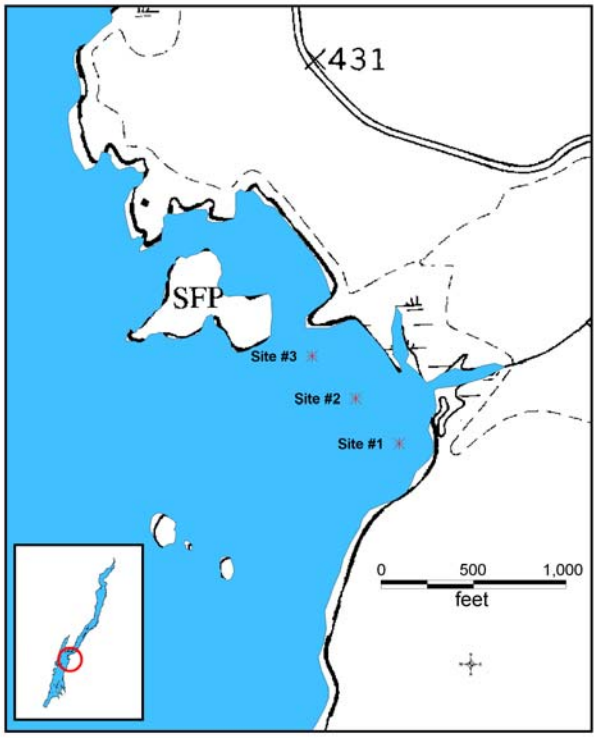


Figure 2.

Analysis. Samples were shipped to a lab (M.J. Reider Associates, Inc.) for analysis. Surface water and sediment samples were analyzed using EPA procedure 314.0 which uses ion chromatography to determine perchlorate in drinking water. The reporting limit outlined by EPA procedure 314.0 for perchlorate in water samples is 0.004mg/L. It is important to note that the lab was able to use an MDL (method detection limit) of 0.0012mg/L. The reporting limit for perchlorate in the sediment samples is 0.02mg/L. Antimony and barium were both analyzed using EPA procedure 200.8. The results were returned to the LGA and compiled for comparison.

Results

Surface water samples. Although it was expected that perchlorate concentrations would be augmented immediately following a fireworks display, the baseline samples as well as the subsequent, weekly, samples revealed that there appeared to be an absence of measurable perchlorate at both the beginning as well as the end of the sampling period (Table 1).

Perchlorate was analyzed using EPA procedure 314.0 which outlines a reporting limit of 0.004mg/L. However, based on the Massachusetts Department of Environmental Protection's drinking water standard of 0.002mg/L it was requested that the reporting limit for our samples be lowered to that same value. The MDL achieved for our samples was 0.0012mg/L, which is lower than the MassDEP's drinking water standard. The lab then commented on its results report that an estimated value of <0.002mg/L for perchlorate can be considered due to no visible peak at the perchlorate peak retention time.

	Perchlorate (ClO4−) mg/L		
Date	**Site 1**	**Site 2**	**Site 3**
6/17/2009	<0.002	<0.002	<0.002
6/20/2009	<0.002	<0.002	<0.002
6/21/2009	<0.002	<0.002	<0.002
7/2/2009	<0.002	<0.002	<0.002
7/4/2009	<0.002	<0.002	<0.002
7/5/2009	<0.002	<0.002	<0.002
7/8/2009	<0.002	<0.002	<0.002
7/10/2009	<0.002	<0.002	<0.002
7/11/2009	<0.002	<0.002	<0.002
7/15/2009	<0.002	<0.002	<0.002
7/17/2009	<0.002	<0.002	<0.002
7/18/2009	<0.002	<0.002	<0.002
7/22/2009	<0.002	<0.002	<0.002
7/24/2009	<0.002	<0.002	<0.002
7/25/2009	<0.002	<0.002	<0.002

Table 1: Perchlorate concentrations at three sampling sites from June 17 to July 25.

This was the case throughout the duration of the sampling period (June 17 – July 25). So while due to the reporting limit of the EPA procedure 314.0 the findings were initially reported at <.0004 mg/L, we feel comfortable reporting the findings as <.002 mg/L, since the laboratory was actually able to achieve a lower MDL than the reporting limit outlined in the procedure. This study is purely exploratory, which is why we feel comfortable reporting our results in this matter. Others might disagree, and wish to consider the findings as <.004 mg/L. Either way, there was no measureable change in level detected in relation to the fireworks events.

Antimony was analyzed using EPA procedure 200.8. The reporting limit for this procedure is 0.005mg/L. The results indicate that throughout the duration of the sampling period, including the baseline samples, concentrations of Antimony remained <0.005mg/L (Table 2).

Barium, which was also analyzed using EPA procedure 200.8, was the only parameter of the three sampled that deviated from the baseline concentrations. The baseline concentration (June 17) at all three sampling sites was 0.006mg/L. The concentration of Barium varied from site to site throughout the duration of the sampling period; however the concentration did not increase over baseline. Concentrations of 0.005mg/L were observed on several occasions and not exclusive to samples taken prior to fireworks displays (Table 3). We found no measureable trends in the Barium data.

Antimony (Sb) mg/L			
Date	**Site 1**	**Site 2**	**Site 3**
6/17/2009	<0.005	<0.005	<0.005
6/20/2009	<0.005	<0.005	<0.005
6/21/2009	<0.005	<0.005	<0.005
7/2/2009	<0.005	<0.005	<0.005
7/4/2009	<0.005	<0.005	<0.005
7/5/2009	<0.005	<0.005	<0.005
7/8/2009	<0.005	<0.005	<0.005
7/10/2009	<0.005	<0.005	<0.005
7/11/2009	<0.005	<0.005	<0.005
7/15/2009	<0.005	<0.005	<0.005
7/17/2009	<0.005	<0.005	<0.005
7/18/2009	<0.005	<0.005	<0.005
7/22/2009	<0.005	<0.005	<0.005
7/24/2009	<0.005	<0.005	<0.005
7/25/2009	<0.005	<0.005	<0.005

Table 2: Antimony concentrations at three sampling sites from June 17 – July 25.

Barium (Ba) mg/L			
Date	**Site 1**	**Site 2**	**Site 3**
6/17/2009	0.006	0.006	0.006
6/20/2009	0.006	0.006	0.006
6/21/2009	0.006	0.006	0.006
7/2/2009	0.005	0.005	0.005
7/4/2009	0.005	0.005	0.006
7/5/2009	0.005	0.005	0.005
7/8/2009	0.006	0.006	0.006
7/10/2009	0.006	0.006	0.005
7/11/2009	0.006	0.005	0.006
7/15/2009	0.006	0.006	0.005
7/17/2009	0.006	0.006	0.006
7/18/2009	0.005	0.006	0.006
7/22/2009	0.006	0.006	0.006
7/24/2009	0.006	0.006	0.006
7/25/2009	0.006	0.006	0.006

Table 3: Barium concentrations at three sampling sites from June 17 – July 25.

Other data collected includes temperature, pH, and depth. This data was collected for each site on every day that sampling occurred. Temperature was recorded because it may help identify the potential for perchlorate selective microbes to grow and consume the contaminant. The pH can have an effect on the retention time during chromatography. Generally as pH increases retention time decreases. This has implications for the identification of a chemical.

Mean temperature for Site 1 was 21.46°C (19.5° C min., 23.5°C max.) (Figure 3). Site 2 had a mean temperature of 21.36°C (19.3°C min., 23.4°C max.) (Figure 4). The mean temperature for Site 3 was 21.46°C (19.4°C min., 23.4°C max.) (Figure 5).

LGA summer staff Jason Smith collected water samples using a Kemmerer bottle for the study.

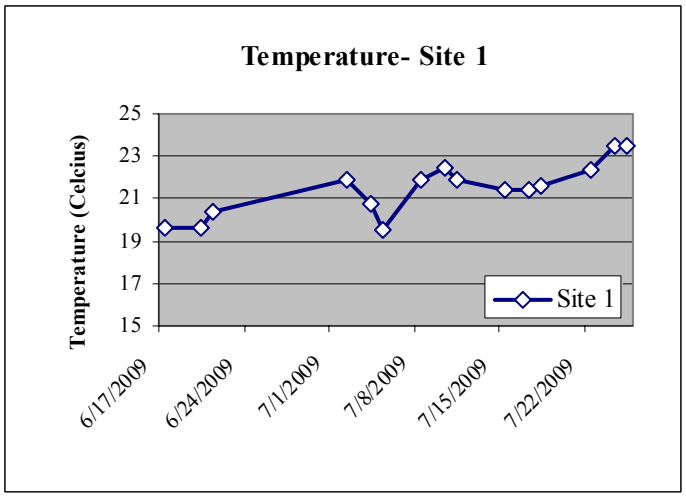


Figure 3: Site 1 temperatures during sampling events.

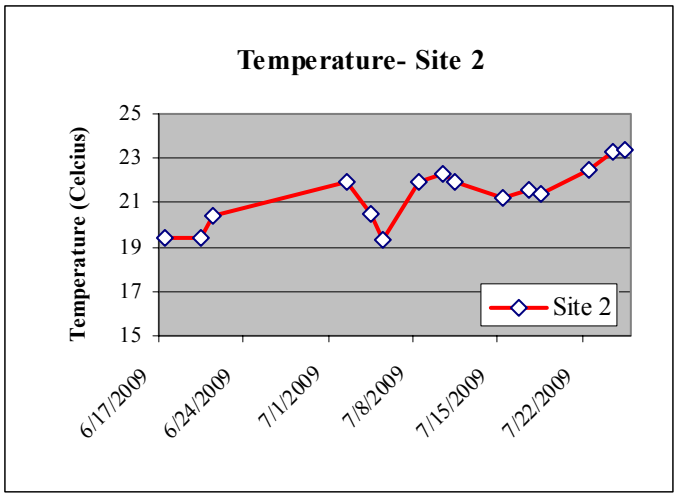


Figure 4: Site 2 temperatures during sampling events.

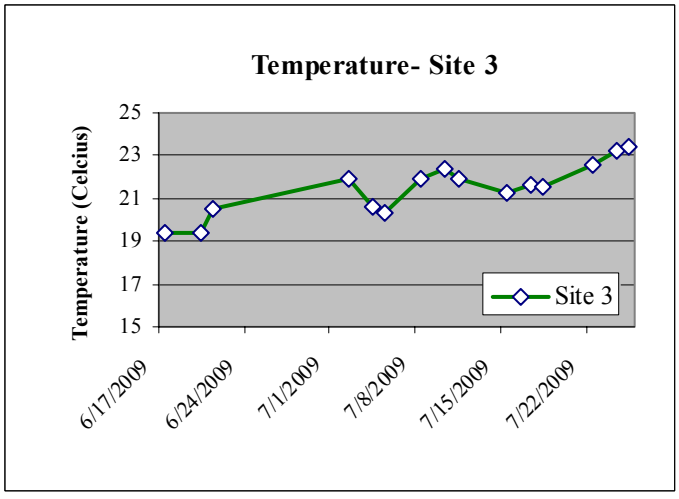


Figure 5: Site 3 temperatures during sampling events.

The values measured at the three sites for pH remained fairly constant (7.6 – 8.0). The mean pH at Site 1 was 7.74 (7.6 min., 7.8 max.) (Figure 6). Site 2 had a mean pH of 7.81 (7.7 – 7.9) (Figure 7). The mean pH at Site 3 was 7.84 (7.8 min., 8.0 max.) (Figure 8).

Depth was measured for the purpose of delineating the three sampling sites. It can also be noted that all three sites are well within the littoral zone. Secchi disk readings for this part of the lake are generally ~ 7.0 meters. Variation in depth at each site although observed, was minimal and can be accounted for by error in the GPS receiver, wind moving the sampling vessel, and variation in lake level. The measured depths as well as the mean depth for each site is shown below (Table 4).

	Depth (feet)		
Date	Site 1	Site 2	Site 3
6/17/09	12.5	17.7	17.2
6/20/09	12.5	17.7	17.2
6/21/09	12.5	17.7	17.2
7/2/09	12.5	17.7	17.2
7/4/09	12.5	17.7	17.2
7/5/09	12.5	17.7	17.2
7/8/09	13.6	18.5	17.1
7/10/09	13	17.6	16.8
7/11/09	13.8	17.7	17.5
7/15/09	12.9	17.9	16.5
7/17/09	13.3	17.9	17.9
7/18/09	13.2	17.9	17.1
7/22/09	12.9	20.2	18.4
7/24/09	12.3	17.9	17.3
7/25/09	12.8	18	17
Mean Depth	12.85333	17.98667	17.25333

Table 4: Depth measurements at Sites 1, 2 and 3 from June 17 – July 25.

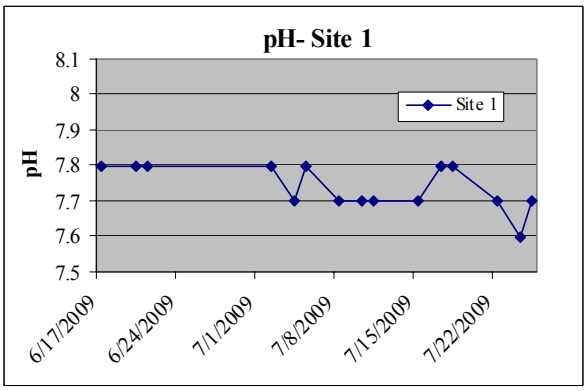


Figure 6: pH at Site 1 during sampling events

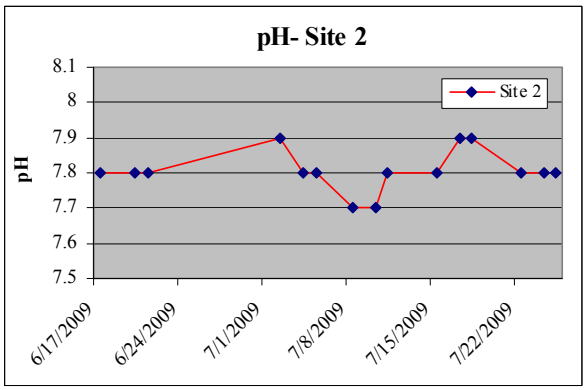


Figure 7: pH at Site 2 during sampling events

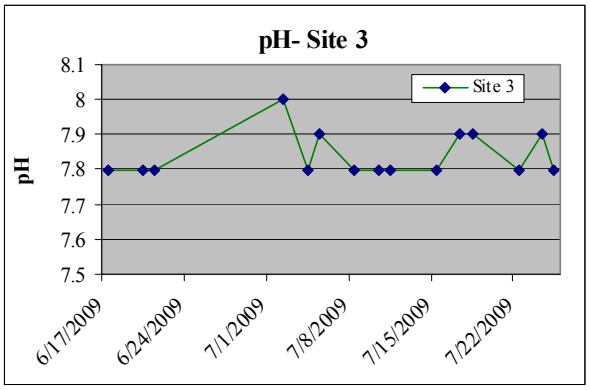


Figure 8: pH at Site 3 during sampling events

Sediment samples. Since there was no evidence of concentrations of perchlorate in the surface water samples, perchlorate was tested in the sediment to see if it was settling out in the water. Our baseline samples were taken at Shelving Rock since it is believed that no firework events have taken place there. Concentrations of perchlorate for the 3 samples taken in the Shelving Rock area were all below the EPA procedure 314.0 reporting limit of 0.02 mg/L. This is also true of the 3 sediment samples that were taken at the three sampling sites within the Lake George village area.

Sediment samples before they were sent to the lab for analysis.

Sediment Samples 10/7/2009	Perchlorate (ClO_4^-) mg/L
Lake George Village—Site 1	<0.002
Lake George Village—Site 2	<0.002
Lake George Village—Site 3	<0.002
Shelving Rock—Site 1	<0.002
Shelving Rock—Site 2	<0.002
Shelving Rock—Site 3	<0.002

Summary and Future Study

Due to concern over the years about the effects of fireworks on Lake George, and lack of available scientific data, we collected some initial samples this past summer. Perchlorate, barium, and antimony, all common components of fireworks, were measured in the water. Perchlorate was also measured in sediment samples. Our samples did not find higher amounts of these pollutants in response to fireworks events held in Lake George Village throughout the summer. Our results showed no change in perchlorate, with perchlorate levels less then 0.002 mg/L for all tests, before and after firework events. We also did not find a change in antimony levels, and while barium levels slightly fluctuated, the results were also not significant. We also found perchlorate levels of less than 0.002 mg/L in the sediment samples from both locations, both near the fireworks and far away from any known fireworks displays.

Photo by Pete Greer

However, we acknowledge that these results are only very preliminary. Other studies elsewhere have found changes in perchlorate levels associated with fireworks. These studies were able to measure smaller amounts of perchlorate than we were able to in this study. There are also many other contaminants associated with fireworks that we did not measure. Others may wish to pursue further studies on this matter, and our findings are available for those purposes.

Perchlorate-free fireworks are available for use, however they cost more than traditional fireworks. Since perchlorate has implications for human health, a switch to perchlorate-free fireworks for fireworks used over Lake George might want to be considered. Our initial findings did not find detectable perchlorate levels in the water attributable to fireworks, so they do not necessarily support the need of this additional expense at this time. However, since this study was by no means comprehensive, we can not know for certain if there is need for a concern over perchlorate or not, and can only weigh our options based on the knowledge we have available to us. This study is just one step in adding to that knowledge base. It still might be a prudent idea to further investigate the costs associated with using perchlorate-free fireworks.

What does seem to make sense to move forward with at this time is a way to track the fireworks displays that occur over Lake George every year, so that we can have a better idea of the number and locations of these events. A simple registration form could be required by licensed fireworks display companies hired to produce a show anywhere in the Lake George watershed. The name of the company, date, time, location, and information on the amount and type of materials used in the show would be very useful information to have. This does not have to be a burden or expense on the fireworks companies, just a simple registration form so that we know what is going off in the air over the lake, and potentially falling into it. When we met with Jeff Alonzo from Alonzo fireworks he agreed that such a registration seemed reasonable and said he had no objection to it. The LGA is in no way against fireworks displays over Lake George. We know that everyone enjoys a good fireworks show. However, if future scientific inquiries determine that there is cause for concern, as stewards of Lake George, we feel that the responsible thing to do is to address the matter and work with our local community in finding a solution.

Lake George is not the only waterbody dealing with trying to balance fireworks for entertainment with water quality concerns. A quick internet search turns up many popular articles on the issue from across the country as well as a few scientific studies. If readers are interested in learning more about fireworks, perchlorate, and water quality, we have provided a few of the sources that we have reviewed on the following page.

Fireworks on Lake George Photo by Eric Paparatto

Selected References Related to Fireworks, Perchlorate, and Water Quality

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