Water Quality Investigation
of
Three Embayments of Tellico Reservoir

by

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with

ADDENDUM:

FOLLOW UP SAMPLING IN 2017

April 2018

Water Quality Improvement Committee
Watershed Association of the Tellico Reservoir

Water Quality Investigation of Three Embayments of Tellico Reservoir

Executive Summary

The goal of this investigation was to better understand the fate of Escherichia coli (E.coli) bacteria in three embayments of Tellico Reservoir that receive water from polluted creeks to provide guidelines to boaters and residents as to when water contact might be unsafe. Water samples were collected once a month from May to September, 2016, in the Bat Creek, Baker Creek and Fork Creek embayments at three locations in each embayment; at an upstream location where water was shallow, at a site near the middle of the embayment, and a downstream site near the mouth. Of the five days of sampling, two, June and September, occurred within 48 hours of rain events of more than an inch of rain.

The embayments of Tellico Reservoir, sampled during the summer of 2016, had excellent recreational water. The E.coli concentrations during the "dryer" sampling periods, May, July, and August, was very low, with a maximum concentration of 54 colonies (per100ml) and an overall geometric mean of 4.0 (N=33). These values are well below the Tennessee criteria for lake waters to be classified suitable for recreational use.

Even with heavy rain events most of the sampled sites had acceptable E.coli levels. But the rain events did show a slug of water with E.coli levels in excess of 500 colonies entering each of the embayments. The duration of the these high E.coli events and the extent of how far a slug of poor quality water progressed through the embayment needs further evaluation.

Additional sampling in the Bat Creek embayment found that it takes a significant rain event to drive the creek water with high E.coli into Tellico Reservoir. It appears that for the summer of 2016 the water of Bat Creek pooled above the Lakeside Drive crossing/culvert, so that bacteria had sufficient time to die before that water entered the reservoir.

During typical days during the swimming/boating period all areas of the three embayments had water with low bacteria as indicated by levels of E.coli, but <u>after a heavy rain event</u> caution should be taken in water contact per the following guidelines;

- Take Caution in contact with water in the upstream areas of the embayments (creeks)
- Take Caution in muddy or turbid water (visibility less than 40 inches).
- After a very heavy rain take Caution in contact with water for 72 hours, if cloudy, 48 hours if sunny, in the upper reaches of Baker and Bat Creek embayments and the mid and upper reaches of the Fork Creek embayment.

Bacteria Concentrations Near the Mouth of Large Creeks Flowing into Tellico Reservoir

Tellico Reservoir is one of the cleaner lakes of the TVA system of lakes throughout the Tennessee Valley. By sampling several embayments, first in 2002 and again in 2016 and 2017, volunteers of the Water Quality Improvement Committee (WQIC) of the Watershed Association of the Tellico Reservoir (WATeR) have confirmed that the reservoir has excellent recreational water suitable for water sports. However, several watersheds of creeks flowing directly into Tellico Reservoir are primarily agricultural land, much of which includes livestock grazing. Because of runoff from these pastures and direct access to the creeks by livestock, these streams have elevated concentrations of Escherichia coli (E. coli) bacteria. E. coli is used as an indicator of fecal contamination. Consequently, the Tennessee Department of Environment and Conservation has classified many creeks flowing directly into Tellico Reservoir as environmentally impaired. Fortunately, except during heavy rain events, these creeks do not have sufficient flow into the reservoir to cause measurable contamination with E. coli.

Even with a heavy rain event (1 ½ inches or more), most of the reservoir maintains E. coli concentrations well below the level of concern. But during these heavy rains, a slug of water with high E. coli levels enters embayments of the reservoir. During the Spring and early Summer, these slugs of water transport not only E. coli, but frequently are also muddy.

As the water from a polluted creek flows into the reservoir, it slows and spreads in the shallow end of an embayment. This exposes any E. coli to sunlight (UV radiation) and to numerous micro-organisms that kill and consume bacteria. During 2017, WQIC volunteers sampled an embayment for five consecutive days after a heavy rain event to determine the penetration of E. coli into the embayment and to measure how long it took for the bacteria to decompose. Based on an analysis of these data**, the WQIC advises that people should avoid contact with water in the shallow end of embayments, where polluted creeks enter the reservoir, for three days following a heavy rain event.** Swallowing or swimming in water with unacceptable levels of pathologic strains of E. coli can lead to an infection..

Although the WQIC have tested the embayments of only three of the larger creeks, it appears reasonable that this trend should be expected for any relatively large creek that flows through pasture land where livestock graze. However, this is not likely a major concern for streams not subjected to livestock grazing. Except for the periods shortly after heavy rainfall, the E coli concentrations in all three of the embayments tested were well below the level of concern. And, with no indications that the downstream portions of the sampled embayments were impacted, WATeR believes that the main body of the lake and coves not receiving creek runoff are not impacted by unacceptable concentrations of E.coli.

The Water Quality Improvement Committee of WATeR is supporting various local agencies in obtaining and administering cost-share grants to implement Agricultural Best Management Practices to prevent manure from reaching the creeks and help to eliminate this health concern.

Acknowledgements

This report documents a project performed by the Water Quality Improvement Committee of the Watershed Association of the Tellico Reservoir (WATeR). The authors wish to thank the Rarity Bay Homeowners Association for financial support for the laboratory analyses of water samples collected in 2016. Under the direction of the authors, the following people assisted in collecting water samples that were subsequently transported to MicroBac Laboratories in Maryville, TN for analysis:

Bill Lemmon
John Rogers
Ray Stephens
Marjorie Waldrop
Patty Wallace

Boats for collecting samples were provided by Ray Stephens and Bill Waldrop.

Those desiring more information concerning this investigation may contact the authors directly, or through the WATeR web site at www.tellicowater.org.

2017 Sampling

Under the direction of the authors, the following people assisted in collecting water samples that were subsequently transported to MicroBac Laboratories in Maryville, TN for analysis:

Garry Lucas
Bill Waldrop
Tom Paul
John Shryock
Fred Evans
Tom Archakis
John Rogers

Boat for collecting samples was provided by Bill Waldrop.

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Water Quality Investigation of Three Embayments of Tellico Reservoir

This project was designed to determine when and where specific areas of Tellico Reservoir might contain high concentrations of bacteria and should be avoided by swimmers. Tellico Reservoir was created when TVA closed the gates of Tellico Dam on November 29, 1979. The reservoir covers 16,500 acres and inundates the lower 33 miles of the Little Tennessee River and the lower 22 miles of the Tellico River. The upstream watersheds of these two rivers are comprised primarily of national forests and the Great Smokey Mountain National Park. With very little industry and no major metropolitan areas in the upstream watershed, this reservoir, commonly known as Tellico Lake, was projected to be one of TVA's cleanest lakes. Except for the legacy of an illegal disposal of transformers in an upstream reservoir prior to the creation of the lake that resulted in PCBs accumulating in catfish, this lake has achieved the expectation of an exceptionally clean lake.

The watersheds of creeks flowing directly into Tellico Reservoir are primarily agricultural land, much of which includes cattle grazing. As a result of runoff from these pastures and direct access to the creeks by cattle, these streams often have elevated concentrations of Escherichia coli (E.coli). An old and poorly maintained upstream wastewater treatment plant and probably from failed septic systems throughout the rural area also contribute to the high bacteria concentrations in the feeder creeks to the reservoir. Consequently, the Tennessee Department of Environment and Conservation (TDEC) classified most creeks flowing directly into the reservoir as environmentally impaired.

Water quality sampling of the lake has consistently shown very low bacteria content. Likewise, sampling upstream in the creeks confirms consistently high E.coli bacteria content. However, there is no data defining E.coli concentrations in the transition zones where creeks with high concentrations of E.coli flow into the backwater of the reservoir. In response to WATeR members' inquiry, TVA and TDEC biologists explained that E.coli cannot survive when exposed to direct sunlight. As the water from a polluted creek flows into the reservoir, it slows and spreads in the shallow end of an embayment which exposes the bacteria to sunlight, quickly killing the bacteria. In 2002, WATeR collected samples in three embayments and laboratory tests confirmed this transition theory, but only for one set of conditions. However, both the TVA and TDEC biologists also cautioned that this process is delayed when it is cloudy or the water is turbid which prohibits sunlight from penetrating the water column.

The goal of this investigation is to better understand the fate of bacteria in this transition zone between the polluted creeks and the reservoir and provide guidelines to boaters and residents when water contact might be unsafe. Volunteers of the Water Quality Improvement Committee (WQIC) of the Watershed Association of the Tellico Reservoir (WATeR) collected water samples monthly throughout the boating and recreational season. The Rarity Bay Home Owners Association provided financial support for analysis of E coli concentrations at Microbac Laboratories in Maryville.

Three embayments were selected for testing because of the density of homes in new communities located adjacent to these embayments (Figure 1):

- Baker Creek Embayment near Foothills Pointe,
- Bat Creek Embayment near Rarity Bay, and
- Fork Creek Embayment near Mialaquo and Chatuga Neighborhoods of Tellico Village.

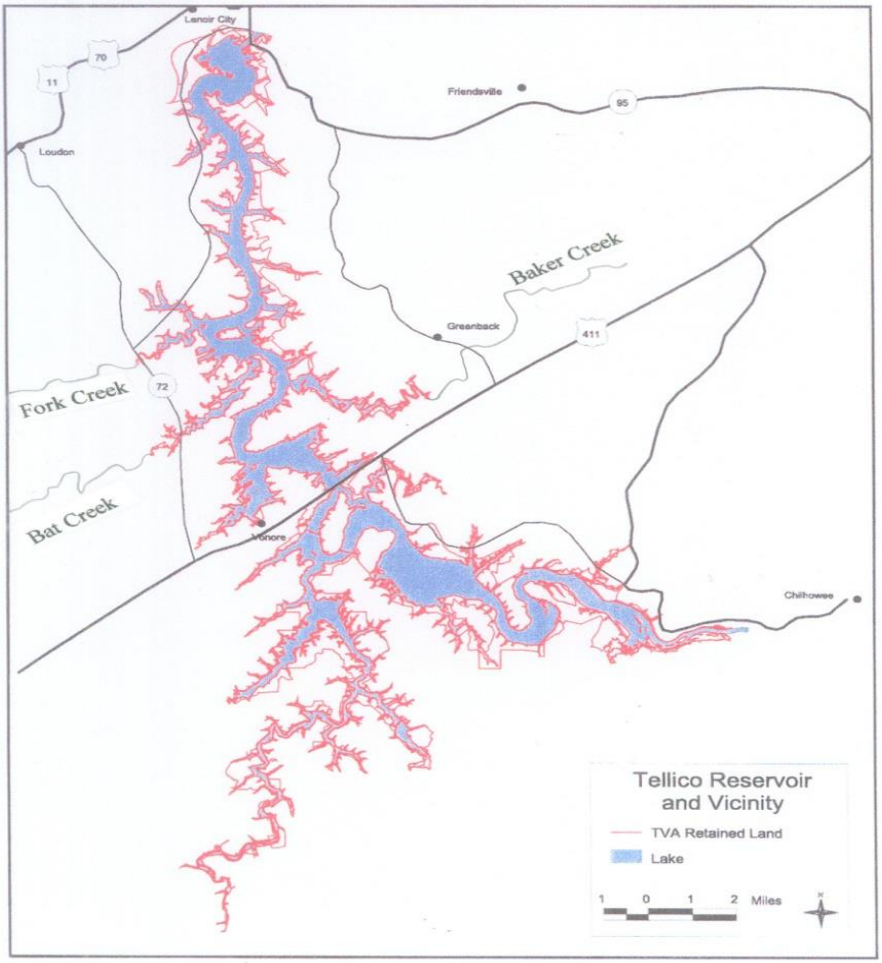


Figure 1: Tellico Reservoir and Vicinity

Water samples were collected from a boat at an upstream location where water was shallow, at a site near the middle of the embayment, and a downstream site near the mouth that is clearly influenced by the reservoir. By design, the sampling times were selected to provide a variety of weather, creek flow, and lake levels. Water samples were collected in sequence on the same morning once a month from May through September. Although only three embayments were tested, the results are probably applicable to any reservoir where creeks flowing into the reservoir have elevated levels of bacteria upstream. Further studies

are being planned to define the duration of times when bacteria levels are high and water contact should be avoided.

TEST PLAN

The main purpose of the sampling was to collect water samples to be tested for concentration of Escherichia coli (E.coli) by the MicroBac Laboratory in Maryville, TN. Other parameters sampled in the field were temperature, both air and water, dissolved oxygen, cloud cover, water appearance and depth where samples were collected. Turbidity was measured using a secchi disk. It was hoped that secchi disk visibility could be used as an indicator of poor water quality. Water Samples were collected at a depth of about 12 inches as per guidelines of the World Health Organization for monitoring bathing waters (Figueras, et.al., 2000). . The E.coli data was measured as, and reported as, Most Probable Number of Colonies per 100ml (MPN/100ml). The E.coli concentration values in Figures 5, 6, 9, 10, 11 and 12 are MPN/100ml, not CFU as listed.

Samples were collected once a month, May to September 2016, at each of three zones in the 3 embayments selected for sampling. For the Bat Creek embayment additional samples were collected to gain further insight as to the possible influence the bacterial condition of the creek had on downstream waters and the embayment, and to ascertain conditions in some of the coves adjoining the main embayment. A limit on the availability of sample bottles for the lab dictated that a few main embayment samples for Bat Creek were collected in other regions of the embayment.

All samples were collected from boats of the volunteers. Seven volunteers participated in the collection of the samples; spending 90 man-hours and 18 outboard hours in the endeavor. Two hundred twenty five miles were driven delivering samples to the lab. Details of the sampling protocol are presented in Appendix A.

The collection of the samples from a boat made it possible that all three embayments were tested in sequence on the same day.

Three sites were selected in each embayment designed to cover primary zone of recreational use of each embayment:

- a. Upstream – Water is very shallow, thereby limiting most boating
- b. Mid-Embayment – A zone of frequent use by boaters, yet a reasonable distance from the main channel
- c. Downstream – Water conditions characteristic of reservoir, near the mouth of the embayment. For the Bat creek embayment the randomly selected sample site was about a mile from the mouth of the creek.

The three sample sites for each embayment are denoted in aerial photographs presented in Figures 2, 3, and 4.

Recent rainfall was recorded from a rainfall gage located on Cheestana Way, in Tellico Village, Loudon, TN (35°40’52 N and 84°15’27 E). The rain data was felt to be generally appropriate to the region for analysis, except for the September sample for the Bat Creek embayment. The team has information from a resident of that area that the September recorded rain event may have been localized and probably the rain fall in the Bat Creek watershed was less than that measured at the gauge.

Figure 2: Aerial Photograph of Sample Sites in Bat Creek Embayment

Figure 3: Aerial Photograph of Sample Sites in Fork Creek Embayment

Figure 4: Aerial Photograph of Sample Sites in Baker Creek Embayment

RESULTS

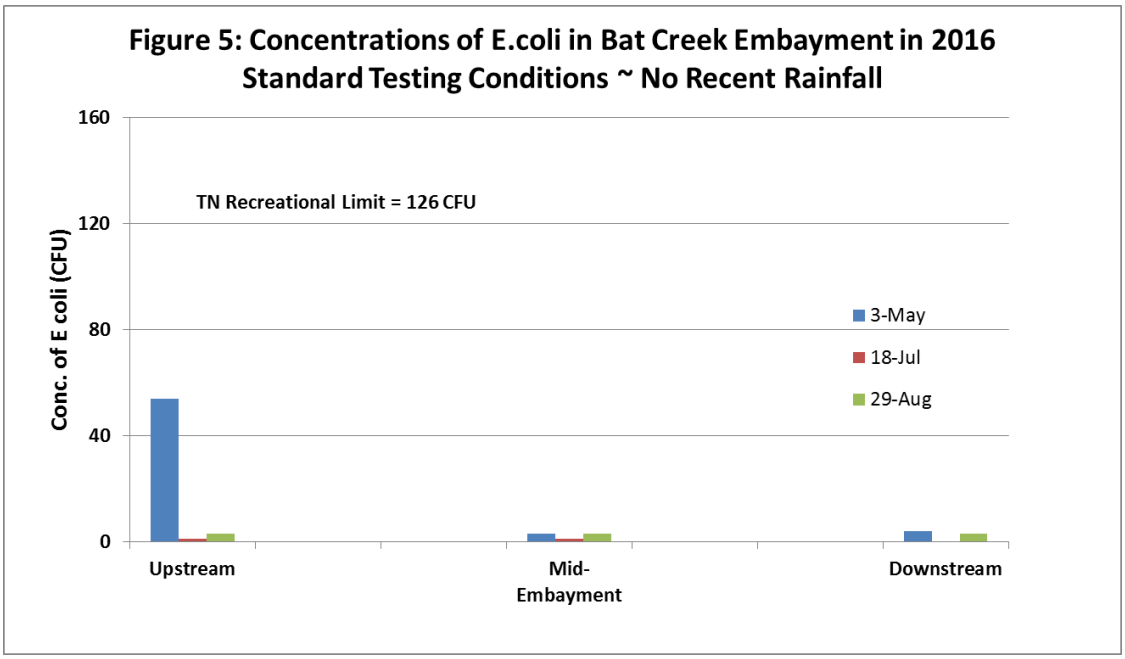
A total of forty eight (48) water samples were collected in the 3 embayments in 5 monthly sampling runs, May through September, 2016. The samples were delivered to the MicoBac Laboratory for analysis of E.coli. Of the five days of sampling, two, June and September, occurred within 48 hours of rain events of more than an inch of rain.

The embayments of Tellico Reservoir, sampled during the summer of 2016, had excellent recreational water. The E.coli concentrations during the "dryer" sampling periods were very low, with a maximum concentration of 54 colonies (MPN/100ml), and an overall geometric mean of 4.0 (N=33). These values are well below the geometric mean criteria of 126 colonies per 100ml and the absolute criteria of 487 colonies per 100ml for lake waters to be classified suitable for recreational use (TN. State Statute Chapter 0400-40-03, April 2013). The higher E.coli concentrations during these months, May, July, August, were generally found in the upper reaches of the embayments.

A discussion of the E.coli results for the samples collected after the rain events will be presented in the following write up for each separate embayment. State statute allows data collected after a significant rain event to be considered as outliers and need not to be used to assess a classification status for a body of water (TN. State Statute Chapter 0400-40-03, April 2013). The WQIC felt that data needed to be collected after rain events to determine if the water would remain acceptable for recreational use.

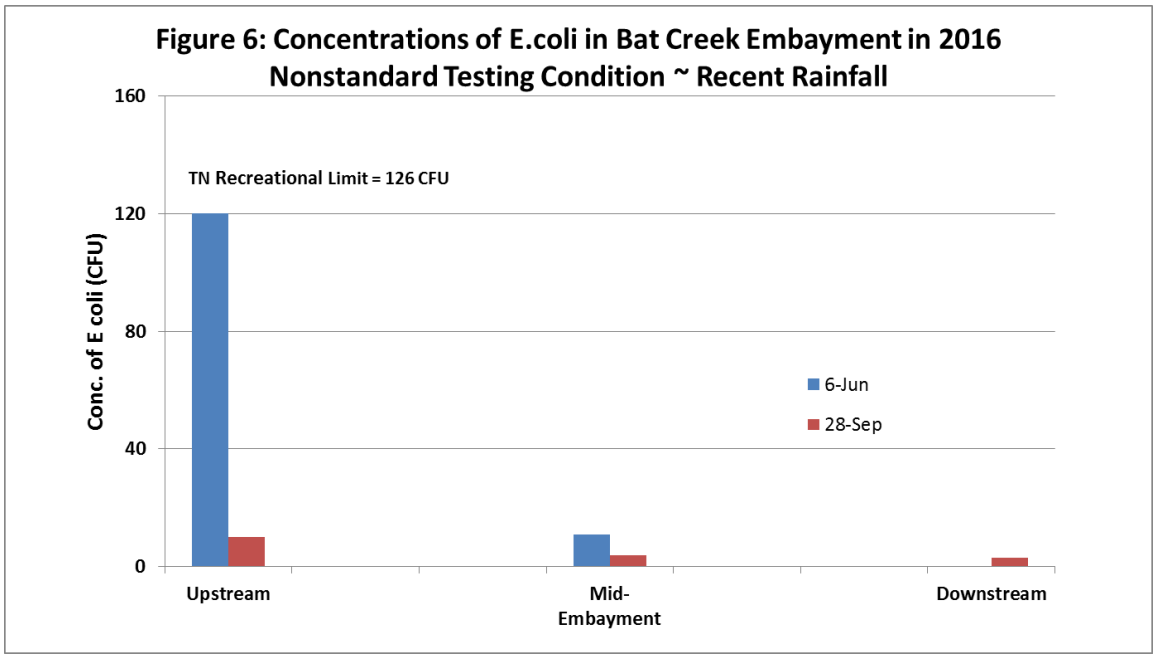
BAT CREEK EMBAYMENT

The E.coli concentrations at the three standard sampling sites, for all the sampled months, May to September, ranged from 0 to 120 colonies (per 100ml) with an overall geometric mean of 5.6 (N=12) (Figures 5 and 6). These values are well below the geometric mean criteria of 126 colonies and the absolute criteria of 487 colonies for lake waters to be classified suitable for recreational use (TN. State Statute Chapter 0400-40-03, April 2013).



The maximum E.coli concentration found in the Bat Creek embayment was found in the June sampling that occurred after several heavy rain events (Figures 6 and 8). The June sampling event occurred about 24 hours after a two day rain event where 4.03 inch of rain fell. This rain event was preceded by a 1.49 inch rain, with only a 24 hour delay between the two events. The creek flowing into the embayment after this rain event was anticipated to have a very high E.coli count. Sampling by WQIC the previous month (May) as part of the Bat Creek Supplemental Environmental Project (SEP) found the E.coli levels where the creek entered the embayment to be high at 870 colonies (per 100ml). There had only been a trace amount of rain preceding that sampling. So, with this heavier rain event, instead of collecting a downstream embayment sample, a sample was collected in the pool above Route 72 to get better insight into what influence the creek was having on the E.coli concentration of the embayment. The E.coli concentration at the original upstream site located at the Highway 72 bridge, was 120 colonies. (This site was the farthest a boat would normally travel in May when the lake was filling from the lowered winter pool level). An alternate sample was collected from the pool upstream of Route 72 (Refer to figure 8 for illustration of the upper embayment sample sites). Although the sample from the pool above Route 72 was collected only about 1,500 feet from the Route 72 bridge site, the E.coli concentration in that

pool was high at 1,700 colonies. Moving downstream from the 72 bridge the E.coli concentration at the mid-embayment sample site was only 11 colonies. It is not known if or how far that slug of high E.coli water extended downstream into the Bat Creek embayment of Tellico Reservoir in the days after the sampling.

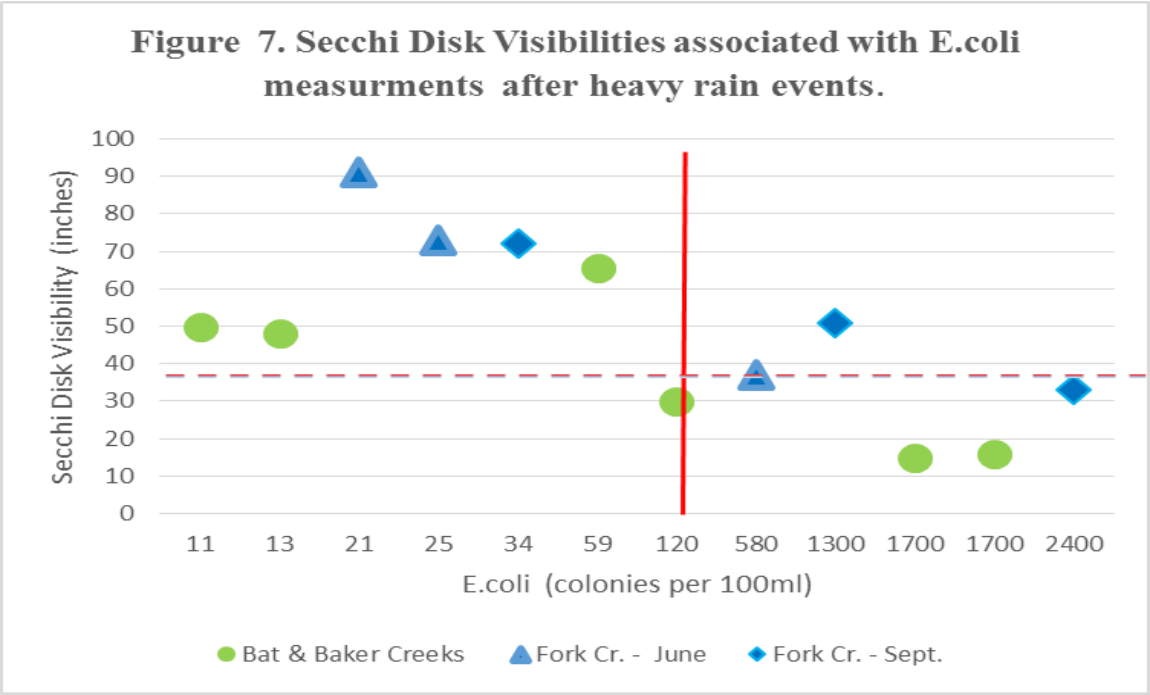


The high E.coli concentrations found after the heavy rain event in June were associated with muddy or murky water where secchi disk visibilities were 30 inches or less for Bat Creek and Baker Creek and less than 40 inches for Fork Creek. (Figure 7). For the September rain event high E.coli were found in Fork Creek with clearer water. A heavy rain in early fall can wash in lots of organic matter from harvested fields. This organic matter seems to neutralize the colloquial properties of mud (personal observation of the co-author).

The September rain event was probably not strong enough to drive Bat Creek water into the embayment. The team has information from a resident of that area that the September recorded rain event may have been localized and probably the rain fall in the Bat Creek watershed was less than that measured at the gauge.

It is suggested that after a heavy rain event the public should exhibit caution in waters upstream of the Highway 72 bridge, and any waters that appear muddy or murky with mud.

During the "dry" sample months (May, July and August) the upstream stations had turbid water with both low water visibility and low E.coli counts.



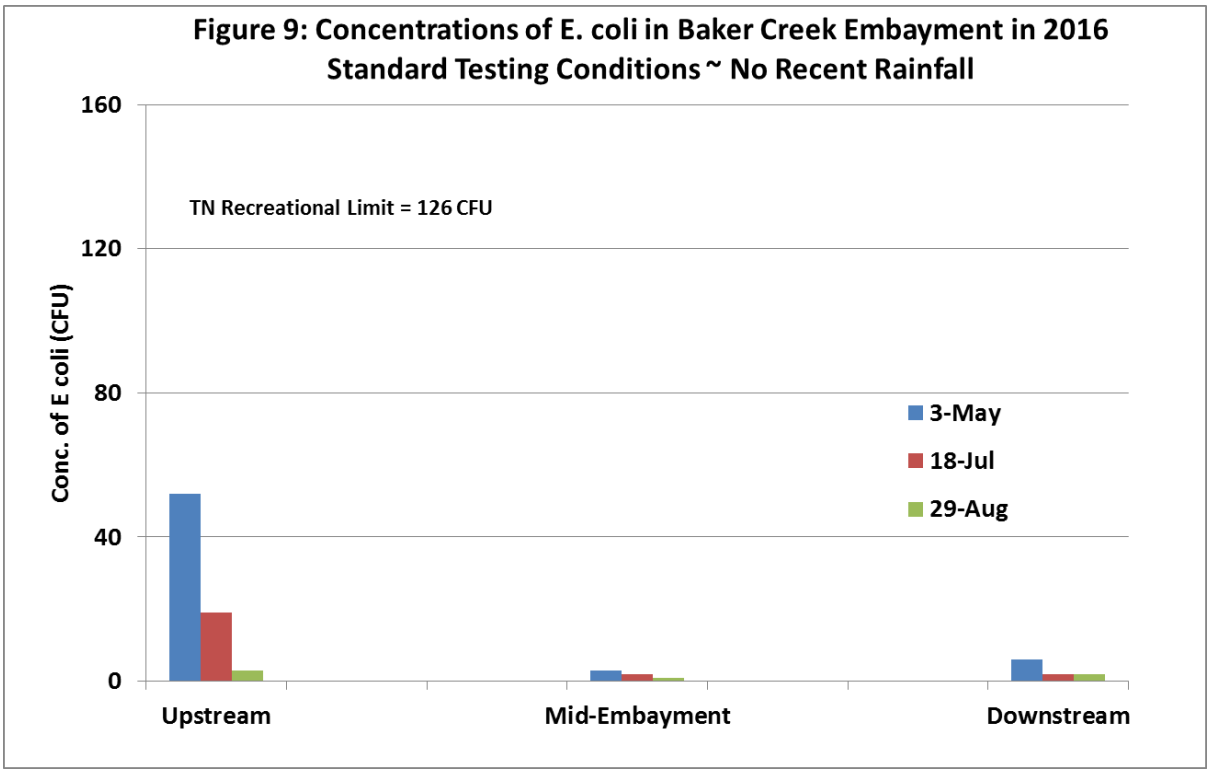
Additional sampling was undertaken in July and August to further evaluate what influence the creek was having on E.coli in the embayment. Sampling by WQIC in 2016 for the Bat Creek Supplemental Environmental Project (SEP) found the E.coli levels where the creek entered the embayment to be high: In the uppermost pool where the creek entered the embayment, the E.coli ranged from 250 to 870 colonies (per 100ml) with a geometric mean of 604 (n=5) .During July and August an additional sample for this embayment study was collected in the pool immediately downstream of the Lakeside Drive crossing of Bat Creek, a mere 1200 feet downstream from where samples were collected for the Bat Creek SEP project. Although E.coli levels in the creek were 870 and 730 colonies, 5 and 7 days, respectfully, prior to sampling in the downstream pool, E.coli in the pool was only 22 and 17 colonies, respectfully. In the next pool downstream, the pool above the 72 bridge, where the E.coli concentration was 1700 colonies in June, it had fallen to a mere 4 colonies in the July sample.

It appears that it takes a significant rain event to drive the high E.coli creek water into the Bat Creek embayment area of Tellico Reservoir. The National Weather Service reported that rainfall for the summer of 2016 was below average. It appears that for the summer of 2016 the water of Bat Creek pooled above the Lakeside Drive crossing/culvert, so that bacteria had sufficient time to die before that water entered the reservoir.

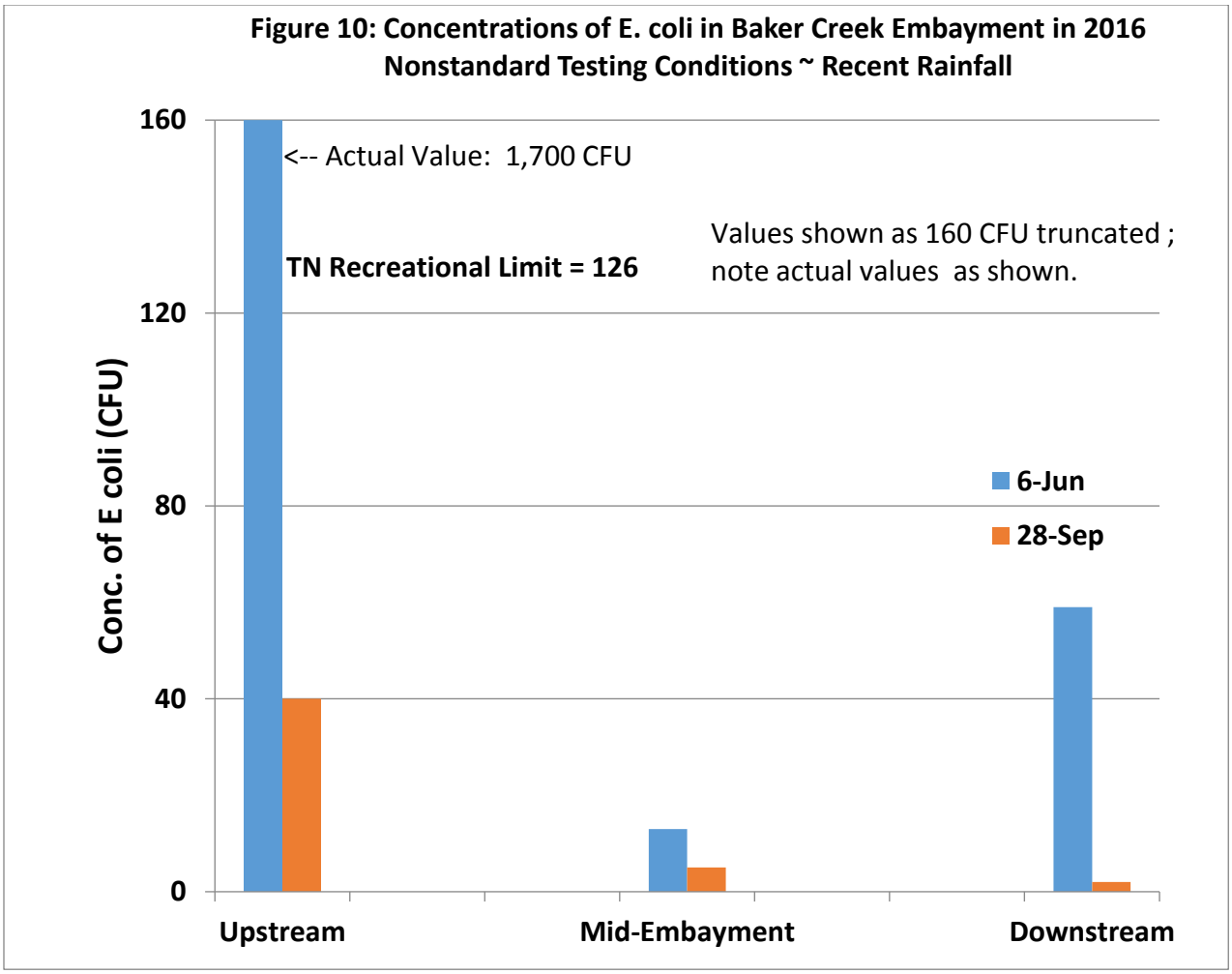
Figure 8. E.coli colonies (MPN/100ml) measured in the upper pools of the Bat Creek embayment. The values in red are those for June, after a heavy rain event. Those values in blue are for the month of July, and green for the month of August.

BAKER CREEK EMBAYMENT

The E.coli concentrations during May, July, and August (Figure 9) ranged from 1 to 52 colonies (per 100ml) with an overall geometric mean of 4.2 (N=9). These values are well below the geometric mean criteria of 126 colonies per 100ml and the absolute criteria of 487 per 100ml for lake waters to be classified suitable for recreational use (TN. State Statute Chapter 0400-40-03, April 2013).



During the months of June and September, when sampling occurred after heavy rains (Figure 10), most of the E.coli concentrations remained low, 2 to 59 colonies, except the uppermost sample site in June the concentration was 1700 colonies. The high E.coli, like that at Bat Creek, was associated with turbid muddy water.



During the June rain event there was a minor spike in E.coli at the downstream station near a residential area. Though this spike was well within acceptable levels it suggested that E.coli during rain events originated from sources other than the incoming creek.

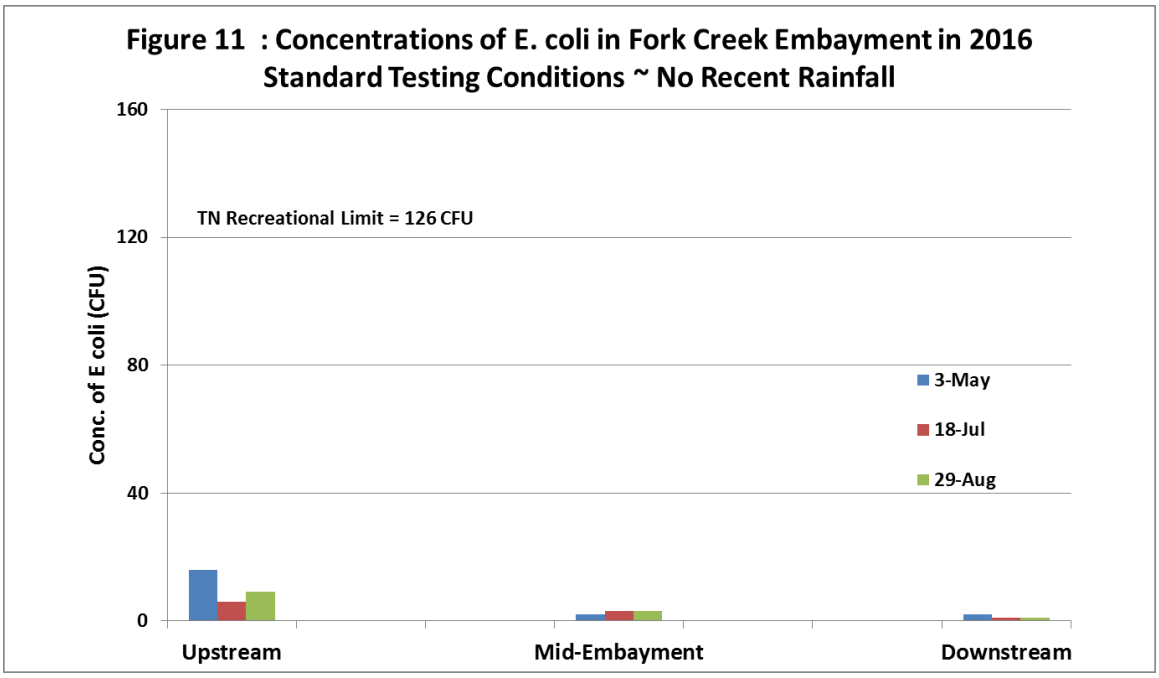
It is not known whether the September rain event was sufficient in the Baker Creek watershed to drive a plume of high E.coli water into the embayment.

It is suggested that after a heavy rain event the public should exhibit caution in waters of the upper part of the embayment, and any waters that appear muddy or murky with mud. The high E.coli concentrations were associated with muddy or murky water where secchi disk visibilities were 30 inches or less (Figure 7).

Note that sampling during the dryer months, water with acceptable levels of E.coli could also be turbid.

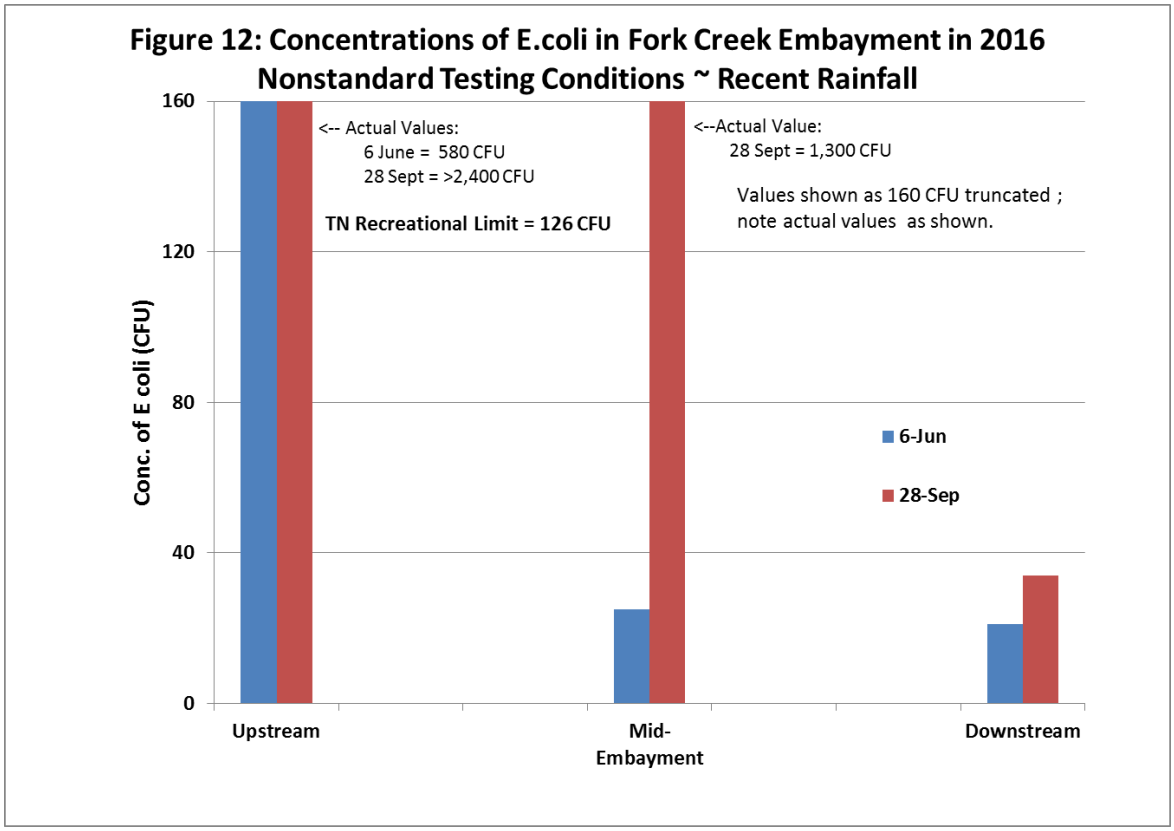
FORK CREEK

The E.coli concentrations during May, July, and August (Figure 11) ranged from 1 to 16 colonies (per 100ml) with an overall geometric mean of 3.2 (N=9). These values are well below the geometric mean criteria of 126 colonies per 100ml and the absolute criteria of 487 colonies per 100ml for lake waters to be classified suitable for recreational use (TN. State Statute Chapter 0400-40-03, April 2013).



During the months of June and September, when sampling occurred after heavy rains, several samples had E.coli concentrations in excess of 500 colonies (Figure 12).

The elevated concentrations of E.coli at the upstream sample site following periods of heavy rainfall were as expected and consistent with results from the other two embayments. However, the high concentration of E.coli recorded at the mid-embayment site was not only inconsistent with data at this location following the June rainfall, but also the trend from the other two embayments following heavy rainfall. Additional sampling of this embayment after a major rainfall event is planned for the summer of 2017 to define the trend of E.coli concentrations over several days.



The high E.coli after rains, unlike Baker and Bat Creeks, did not always appear associated with muddy or turbid water. Where in Bat and Baker Creeks high concentrations of E.coli were found in water with secchi disk visibilities 30 inches or less, for Fork Creek, after heavy rains, high concentrations of E.coli were found in water with higher secchi disk visibilities (Figure 7). . A heavy rain in early fall can wash in lots of organic matter from harvested fields. This organic matter seems to neutralize the colloquial properties of mud (personal observation of the co-author)

The September samples were collected about 48 hours after a heavy rain event. Although the State of Minnesota recommends that swimmers avoid water contact for 24 hours after a heavy rain event (http://www.mnbeaches.org/advice/risk.html), our data suggest water contact should be delayed until the third day after a heavy rain.

CONCLUSIONS

The general thesis that the creeks entering the embayments had high E.coli, but the E.coli in the embayments themselves were at levels to classify the water as acceptable for recreational use was <u>verified</u>.

Even with heavy rain events most of the sampled sites had acceptable E.coli levels. But the rain events did show a slug of water with E.coli levels in excess of 500 colonies (per 100ml) entering each of the embayments. The duration of the these high E.coli events and the extent of how far a slug of poor water progressed through the embayment needs further evaluation.

The State of Minnesota recommends that swimmers wait 24 hours after a heavy rain event to resume swimming (http://www.mnbeaches.org/advice/risk.html). The duration of high concentrations of E coli in an embayment after a major rainfall is difficult to predict. One study of the rate of E coli decay along a beach (Whitman, et al 2004) indicated that elevated levels may persist for several days under cloudy conditions. However, considering the major differences in the hydrology and probably meteorology between a beach and fluctuating elevations of an embayment of a reservoir that is fed by a flowing creek, the accuracy of such predictions is questionable, especially involving predicting unsafe conditions for water contact. Instead, a water sampling project is recommended to provide site specific data as a guideline. Such a project would entail collecting daily water samples for several days at multiple sites in an embayment for several days following a rain event of at least 1.5 inches. Other parameters such as water clarity should also be measured and hopefully correlated with laboratory results of E coli concentrations in an attempt to provide local residents with guidance as to when conditions may be unsafe for swimming. Such a study is in the planning stage for execution in the summer of 2017.

For several years, the WQIC of WATeR has been actively initiating and supporting grants and other activities to implement agricultural Best Management Practices in each of these three watersheds. These cost-share programs include activities to prevent cattle from having direct access to these streams and in one case to promote construction of a new wastewater treatment plant. When fully implemented, these activities should reduce the concentrations of E.coli entering the creeks upstream of these three embayments, making it safer for water sports throughout the boating season.

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Appendix A

SAMPLING PROTOCOL

- Equipment custodian will calibrate meter (Oakton PD450) the morning of the sampling, prior to boarding boat.
- Sampling Crew (2 samplers and boat driver) and transport boat will meet, so prior to leaving, a meeting will be held to discuss protocol and fill out any appropriate paperwork.
- Maneuver boat into, and stop boat, in water about 4 to 5 feet (1.2-1.5 meter) deep, while heading boat into the wind. (Note; The slope of the shore and boat operators caution made acquiring this objective difficult, so the objective was changed to try to collect samples in 7-8 feet of water. And, the slope of the shore in several instances made even this new criteria not obtainable).
- Put on a fresh pair of latex gloves.
- Select the appropriate bottle for the site (lab should have bottles labeled by site (creek and zone). Label the sample bottle lid with time, date and sample site.
- Holding bottle by the base, open bottle with opening facing downward, remove the cap without touching inside of the bottle or inside of the cap. Insert the bottle to elbow depth; then turn bottle upwards to fill. This will obtain a sample about 12 inches below the surface.
- After retrieving the bottle, flick it to leave an air space, but maintain at least 100ml sample. Tightly replace the cap without, at any time, touching the inside of the cap. Shake the bottle to mix preservative.
- Place the sample in zip-lock bag, squeeze out air, close zip-lock and bury sample in cooler of ice.
- While one person is collecting lab sample, helper could be recording time and GPS coordinates.
- Use meter (Oakton PD450) to record air temperature, then water temperature and dissolved oxygen at surface, at sample depth (12 inched deep) and at 10 feet deep (limit of probe cable).
- Measure secchi disk visibility at level where disc disappears and then again when it appears when being retrieved.
- Fill out data sheet accurately and completely.
- Samples must be at lab within 8 hours, preferably within 6 hours.

Appendix B

Tables of Data from Sampling Events

The E.coli data was measured as and is listed in these Appendix tables as Most Probable Number (MPN) of Colonies per 100ml. Visible Water Depth was measured using a secchi disk. The E.coli concentration values in Figures 5, 6, 9, 10, 11 and 12 are MPN/100ml (not CFU as listed).

Bat Creek Embayment

Date	**Location**	**Time**	**E.coli Conc**	**Water Depth**	**Water Temp.**	**Air Temp**	**Cloud Cover**	**Visible Depth**	**Rainfall in 48 Hrs.**
			MPN	Ft.	F	F	%	inches	inches
3 May	Upstream	1009	54	7.1	72	65	60	31	0.33
	Mid-Embay	1025	3	6	73	69	70	58.5	0.33
	Downstream	1035	4	8.5	73	69	80	62	0.33
6 June	Upstream	1220	120	6	81	81	40	30	4.02
	Mid-Embay	1235	11	8	82	81	50	59	4.02
	Downstream	1245	ND					72	4.02
18 July	Upstream	932	1	7	86	80	5	39.5	0
	Mid-Embay	948	0	8	86	83	5	45	0
	Downstream	955	ND	34	87		5	59	0
19 Aug	Upstream	935	3	8	85	75	0	37.5	0.04
	Mid-Embay	ND							0.04
	Downstream	905	3	11	84	74	0	71	0.04
28 Sep	Upstream	1000	10	10	75	61	0	33	
	Mid-Embay	1010	4	15	74	65	0	59	
	Downstream	1035	1	11	76	62	0	71	

Baker Creek Embayment

Date	Location	Time	E coli Conc.	Water Depth	Water Temp.	Air Temp.	Cloud Cover	Visible Depth	Rainfall in 48 Hrs.
			MPN	Ft.	F	F	%)	inches	inches
3 May	Upstream	905	52	3.4	70	60	100	22	0.33
	Mid-Embay	931	3	12	73	64	100	48	0.33
	Downstream	940	6	8	72	64	90	82	0.33
6 June	Upstream	1314	1,700	4	78	81	80	16	4.02
	Mid-Embay	1325	13	4	82	78	85	48	4.02
	Downstream	1339	59	8	81	79	85	65.5	4.02
18 July	Upstream	1035	19	6	87	80	5	23	0
	Mid-Embay	1023	2	12	87	82	5	50	0
	Downstream	1012	2	9	86	80	5	52	0
19 Aug	Upstream	1032	3	4	85	80	5	23	0.04
	Mid-Embay	1047	1	4	85	82	10	59	0.04
	Downstream	1100	2	9	84	81	10	68	0.04
28 Sep	Upstream	915	40	5	72	62	50	19	1.39
	Mid-Embay	930	5	24	72	62	20	39	1.39
	Downstream	945	2	11	72	60	0	74	1.39

Fork Creek Embayment

Date	Location	Time	E coli Conc.	Water Depth	Water Temp.	Air Temp.	Cloud Cover	Visible Depth	Rainfall in 48 Hrs.
			MPN	Ft.	F	F	%	inches	inches
3 May	Upstream	1105	16	8.5	73	69	60	55	0.33
	Mid-Embay	1130	2	16.3	73	72	80	61.5	0.33
	Downstream	1140	2	13.5	73	72	60	86	0.33
6 June	Upstream	1108	580	4.5	81	75	40	37	4.02
	Mid-Embay	1121	25	7	81	79	40	73	4.02
	Downstream	1133	21	22	80	81	30	91	4.02
18 July	Upstream	1142	6	4	87	86	30	33.5	0
	Mid-Embay	1130	3	4	87	82	30	42	0
	Downstream	1116	1	50	86	82	30	57.5	0
19 Aug	Upstream	1127	9	6	86	81	10	39.5	0.04
	Mid-Embay	1141	3	7	86	83	20	54.5	0.04
	Downstream	1152	1	34	86	85	20	79	0.04
28 Sep	Upstream	1045	>2400	6	73	70	0	33	1.39
	Mid-Embay	1100	1,300	31	73	61	0	51	1.39
	Downstream	1120	34	21	73	62	0	72	1.39

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ADDENDUM

FOLLOW UP SAMPLING IN 2017

Bacteria Concentrations Near the Mouth of Large Creeks Flowing into Tellico Reservoir

ADDENDUM

Water Quality Investigation of Three Embayments of Tellico Reservoir

Follow-up Sampling in 2017

Table of Contents

Introduction

Tellico Reservoir is one of the cleaner lakes of the TVA system of lakes throughout the Tennessee Valley. By sampling the Baker Creek, Bat Creek, and Fork Creek embayments, first in 2002 and again in 2016, volunteers of the Water Quality Improvement Committee (WQIC) of the Watershed Association of the Tellico Reservoir (WATeR) have confirmed that the reservoir has excellent recreational water suitable for water sports. However, several watersheds of creeks flowing directly into Tellico Reservoir are primarily agricultural land, much of which includes livestock grazing. Because of runoff from these pastures and direct access to the creeks by livestock, these streams have elevated concentrations of Escherichia coli (E. coli) bacteria. E. coli is used as an indicator of fecal contamination. Consequently, the Tennessee Department of Environment and Conservation has classified many creeks flowing directly into Tellico Reservoir as environmentally impaired for bacteria.

The general thesis, during the 2016 sampling, that the creeks entering the embayments had high E.coli, but the E.coli in the embayments themselves were at levels to classify the water as acceptable for recreational use was verified. Fortunately, except during heavy rain events, the creeks do not have sufficient flow into the reservoir to cause a contamination concern with E. coli. During typical days during the swimming/boating period all areas of the three embayments had water with low bacteria as indicated by levels of E.coli.

Even with heavy rain events most of the sites sampled in 2016 had acceptable E.coli levels. But the rain events did show a slug of water with E.coli levels in excess of 500 colonies (per 100ml) entering each of the embayments. WATeR presented the following guidelines for water contact after a heavy rain event;

- Take Caution in contact with water in the upstream areas of the embayments (i.e. the creeks)
- Take Caution in muddy or turbid water (visibility less than 40 inches).
- After a very heavy rain take Caution in contact with water for 72 hours, if cloudy, 48 hours if sunny, in the upper reaches of Baker and Bat Creek embayments and the mid and upper reaches of the Fork Creek embayment.

The duration of the these high E.coli events and the extent of how far a slug of poor water progressed through the embayment was evaluated in the Fork Creek embayment in 2017. The objective of the Fork Creek sampling was to determine the duration and extent of possible E.coli contamination of the embayment following a heavy rain event. The plan was to collect water samples for several consecutive days at multiple sites in the Fork Creek embayment following a rain event of at least 1.5 inches.

Fork Creek was chosen as the embayment to sample in 2017 for the following reasons:

- The Fork Creek embayment had high E.coli concentrations after heavy rain events in June and September, 2016.
- The Fork Creek embayment is relatively short in length, compared with the other embayments sampled in 2016.
- The Fork Creek embayment shoreline is within a residential area.
- The logistics for a five day sampling using volunteers favored the Fork Creek embayment.

TEST PLAN

Water samples were collected to be tested for concentration of Escherichia coli (E.coli) by the MicroBac Laboratory in Maryville, TN. Other parameters sampled in the field were temperature, both air and water, cloud cover, water appearance, turbidity, and depth where samples were collected. Turbidity was measured as visibility using a secchi disk. Water Samples were collected at a depth of about 12 inches as per guidelines of the World Health Organization for monitoring bathing waters (Figueras, et.al., 2000). The E.coli data was measured as, and reported as, Most Probable Number of Colonies per 100ml (MPN/100ml).

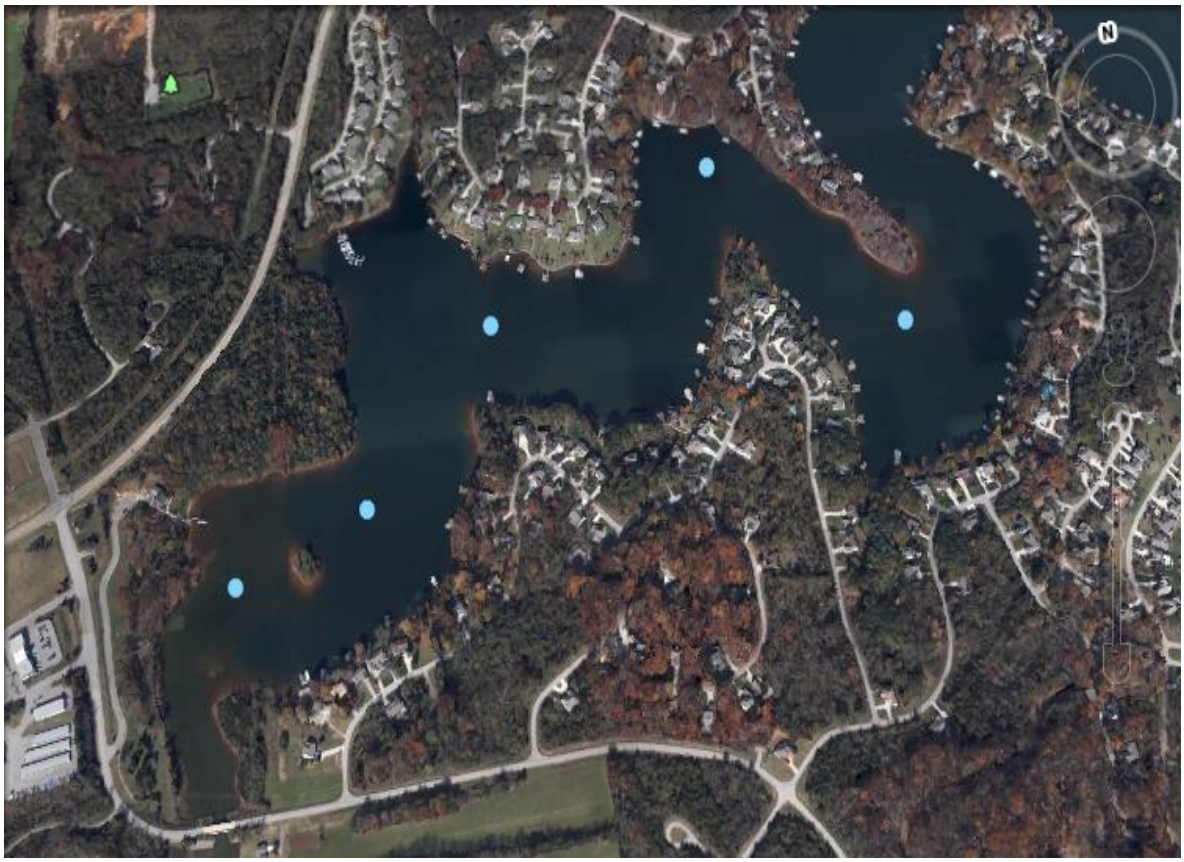
The criteria for a date to sample:

- No significant rainfall for two previous weeks;
- Rainfall of at least 1.5 inches in 24 hours;
- Rain event preferred during weekend, but no later than Tuesday
- Sunny weather preferred with no significant rain predicted for at least 3 days.

The criteria for sampling was met after a 1.8 inch rain event on Sunday October 8, 2017. This rain event took place after prolong dry period of about 2 weeks. Although not fully substantiated, it has been hypothesized that E.coli contamination may be exacerbated when the rain event is preceded by an extended dry period when manure has accumulated in the pasture or near the creek. . Examination of the rainfall record reveals that such a combination of heavy rain preceded by two or more weeks of no rain is relatively rare, occurring only twice during the boating season of 2017. Samples were collected for 5 consecutive days, beginning October 9, 2017 at 5 sites in the upper portion of Fork Creek embayment (refer to Figure on Page 35).

Sites sampled in Fork Creek embayment in 2017.

Site	Site Name	Location
Fork 1	Mialaqua Bridge	Downstream of Mialaqua Bridge at point in lake about midway along a line between first pier on North shore and first pier on South shore
Fork 2	Inagehi Way Island	1st buoy past island (second buoy)
Fork 3	Chatuga Way shore	past 2nd buoy after island (3rd buoy; green buoy across from Marina) and collect sample in middle of channel out from red pier
Fork 4	Inagehi Circle Point	Upstream buoy of the group of 3 buoys off of the point on Inagehi Circle
Fork 5	Kiyuga Lane Point	Next buoy downstream of the group of buoys; off of point on Kiyuga Lane



Fork 1 Fork 2 Fork 3 Fork 4 Fork 5

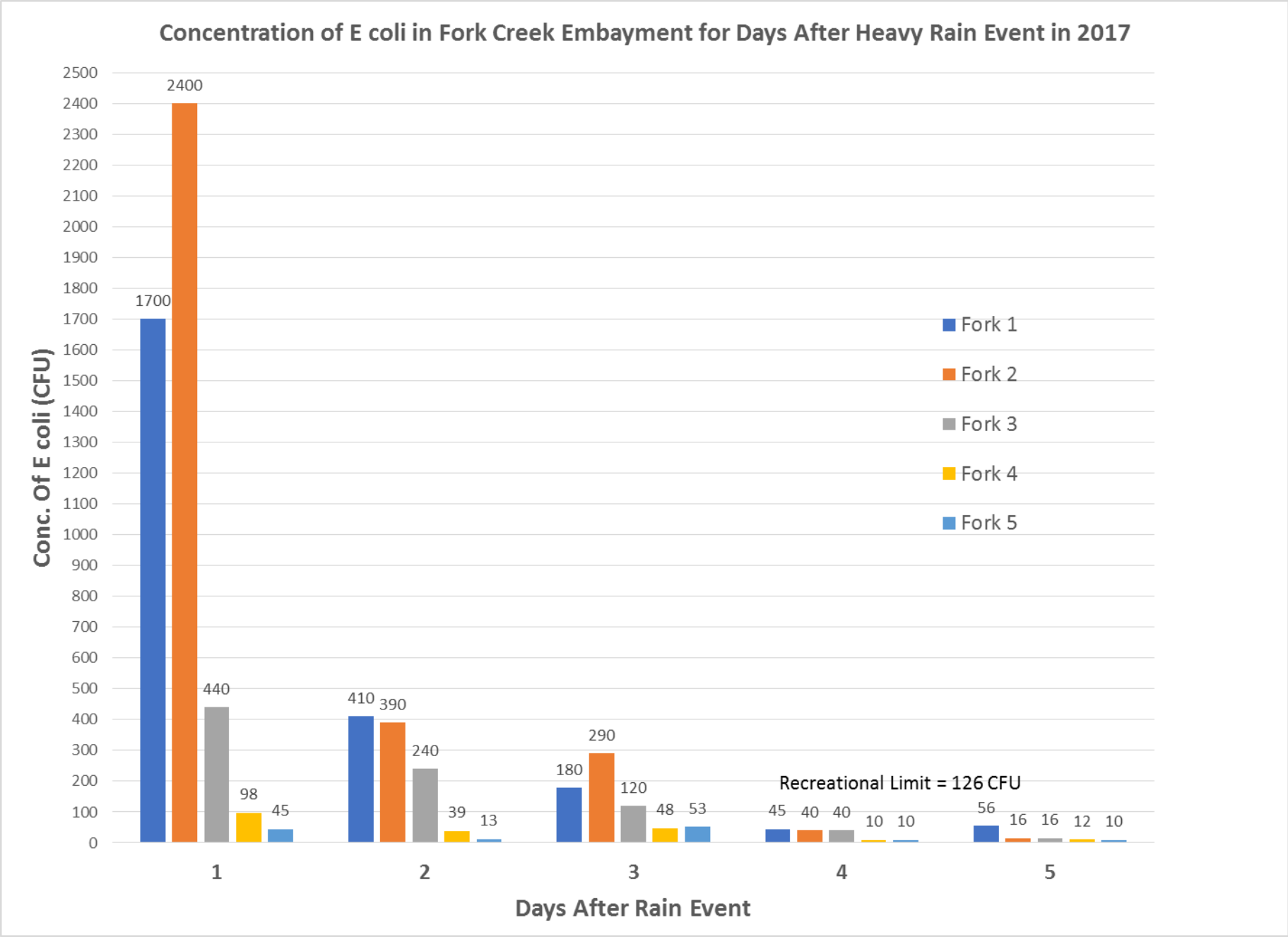
Although the sampling occurred late in the swimming season, water temperature was similar to the September 2016 sampling of Fork Creek (low 70's F), and swimmers were observed in Tellico Reservoir the weekend prior to the rain event.

All samples were collected from a pontoon boat using a pole to collect the samples. Seven volunteers participated in the collection of the samples; spending 58 man-hours and 7.5 outboard hours in the endeavor.

RESULTS

A total of twenty five (25) water samples were collected in the Fork Creek embayment from 5 sites over a 5 day period, beginning on October 9, 2017. The highest E.coli concentrations were over 2400 (MPN/100ml) on day one; 410 on day 2; 290 on Day 3; and 56 for days 4 and 5 (refer to Figure 13). Sample sites Fork 4 and Fork 5 did not have E.coli concentrations above 100 MPN during any of the sample days. All sites were below 60 MPN by the fourth day. The sky was mostly overcast days one, two, and three; and clear on days 4 and 5. The source of the water turbidity for all the samples appeared to be from phytoplankton.

Sample site Fork 4 was sampled both in 2016 and 2017. During 2017 the maximum E.coli concentration found was 98 MPN. The E.coli concentration at this site in September 2016 was 1,300 MPN.


Concentration of E coli in Fork Creek Embayment for Days After Heavy Rain Event in 2017
Conc. Of E coli (CFU)
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
1700
2400
440
98
45
410
390
240
39
13
180
290
120
48
53
45
40
40
10
10
56
16
16
12
10
Recreational Limit = 126 CFU
Fork 1
Fork 2
Fork 3
Fork 4
Fork 5
1
2
3
4
5
Days After Rain Event

CONCLUSION

During 2017, WQIC volunteers sampled the Fork Creek embayment for five consecutive days after a heavy rain event to determine the penetration of E. coli into the embayment and to measure how long it took for the bacteria to decompose. The results confirmed the WQIC recommendation in 2016 regarding water contact following a heavy rain event. Based on an analysis of the data**, the WQIC advises that people should avoid contact with water in the shallow end of the embayment, where polluted creeks enter the reservoir, for three days following a heavy rain event.** Swallowing or swimming in water contaminated with pathologic strains of E. coli can lead to an infection, with symptoms of abdominal pain, diarrhea, and fever. E.coli bacteria is an indicator of recent fecal contamination. As such, other more serious pathogens may be present at high concentrations of E.coli.

Other recommendations made after the 2016 sampling concerning water contact were;

- Take Caution in contact with water in the upstream areas of the embayments (i.e. the creeks)
- Take Caution in muddy or turbid water (visibility less than 40 inches).

Although the WQIC have tested the embayments of only three of the larger creeks, it appears reasonable that this trend should be expected for any relatively large creek that flows through pasture land where livestock graze. However, this is not likely a major concern for streams not subjected to livestock grazing. Except for the periods shortly after heavy rainfall, the E coli concentrations in all three of the embayments tested were well below the level of concern. And, since when sampling during heavy rain events the downstream portions had only small increases in E.coli, well within acceptable levels, the WQIC believes that the main body of the lake and coves not receiving creek runoff maintain acceptable concentrations of E.coli after heavy rain event.

It should be noted that livestock are not the only possible source of bacteria to a body of water, and that rain events can wash in harmful bacteria from sources along the shore. For that reason the State of Minnesota recommends that swimmers wait 24 hours after a heavy rain event to resume swimming, even in waters with no development.

The relationship between rainfall volume and E.coli concentration is not as linear as would be hoped. This situation could be the result of a need for more rain gauges to be monitored in the watershed. Rain events in the Tellico Reservoir watershed can be intense but quite local in intensity.

The Water Quality Improvement Committee of WATeR is supporting various local agencies in obtaining and administering cost-share grants to implement Agricultural Best Management Practices to prevent manure from reaching the creeks and help to eliminate this health concern.

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APPENDIX C

Tables of Data from Sampling in 2017

Date	Site	Location	Time	E coli Conc.	Water Depth	Water Temp.	Air Temp.	Cloud Cover	Secchi Depth
				MPN	Ft.	F	F	%	inches
9 Oct.	Fork 1	Mialaqua Bridge	957	1700	6.5	70	72	75	42
	Fork 2	Inagehi Way Island	1005	>2400	15.4	70	77	50	43
	Fork 3	Chatuga Way shore	1019	440	22	70	77	50	46
	Fork 4	Inagehi Circle Point	1029	98	17.1	70	77	60	53
	Fork 5	Kiyuga Lane Point	1036	45	12.2	71	79	60	54
10 Oct.	Fork 1	Mialaqua Bridge	1318	410	4.3	72	78	100	40
	Fork 2	Inagehi Way Island	1322	390	15	71	78	100	42
	Fork 3	Chatuga Way shore	1330	240	22.2	72	78	100	48
	Fork 4	Inagehi Circle Point	1344	39	19	71	78	95	54
	Fork 5	Kiyuga Lane Point	1355	14	15	72	78	90	55
11 Oct.	Fork 1	Mialaqua Bridge	1400	180	5.2	73	78	50	31
	Fork 2	Inagehi Way Island	1405	290	15	74		50	40
	Fork 3	Chatuga Way shore	1412	120	23.2	72		50	42
	Fork 4	Inagehi Circle Point	1419	48	31.6	74		40	45
	Fork 5	Kiyuga Lane Point	1425	53	25.7	73		40	43

Date	Rainfall in 24 Hrs. (inches)
9 Oct.	1.83
10 Oct	0.00
11 Oct	0.02
12 Oct	0.01
13 Oct	0.00

Date	Site	Location	Time	E coli Conc.	Water Depth	Water Temp.	Air Temp.	Cloud Cover	Secchi Depth
				MPN	Ft.	F	F	%	inches
12 Oct.	Fork 1	Mialaqua Bridge	1400	45	4.1	72	74	0	37
	Fork 2	Inagehi Way Island	1407	40	16	72	74	0	38
	Fork 3	Chatuga Way shore	1410	40	24.5	72	74	0	41
	Fork 4	Inagehi Circle Point	1418	10	31	71	74	0	51
	Fork 5	Kiyuga Lane Point	1425	10	18	71	74	0	55
13 Oct.	Fork 1	Mialaqua Bridge	1325	56	5.5	72	84	5	35
	Fork 2	Inagehi Way Island	1335	16	15.5	72	82	5	43
	Fork 3	Chatuga Way shore	1340	16	23.5	73	82	5	44
	Fork 4	Inagehi Circle Point	1345	12	31.2	72	83	5	52
	Fork 5	Kiyuga Lane Point	1353	10	16.6	72	83	5	50