

A Water Quality Survey of the Back- country
in
Bryce Canyon National Park

by
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Back-country Water Quality Survey

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The scenic splendor of Bryce Canyon National Park has captured the eyes and minds of millions of visitors for many years. Among these visitors are an ever increasing number of people wanting to get a more intimate look at the park than that afforded by a car trip around the rim. These people often resort to hiking a day trip or frequently an overnight hike. All of these people need water for drinking while on the trail. The only water available along the back-country trails is from unprotected surface sources, sometimes of dubious quality and availability. Many people see the natural beauty of the park and feel that such "Wilderness" must have pure waters. A quantitative analysis was conducted to document whether this is fact or fiction.

Object: Determine the bacterial quality of major back-country water sources as indicated by the presence/ absence of fecal coliform indicator species (Escherichia coli) and fecal streptococci (Group D Lancefeld).

Purpose: Those sources which contain high bacterial levels indicative of fecal pollution can be identified. Causative factors for contamination can possibly be shown by inspection and perhaps mitigated.

Goal: To provide hikers with the optimum quality of drinking water while visiting at Bryce Canyon National Park.

The quality or potability of drinking water can be measured by many standards. These may be such characteristics as chemical content, temperature, odor, turbidity, presence of pathogenic organisms, and availability for use. This study will be concerned primarily with the last two characteristics.

Water availability is an obvious consideration for this project. The maintenance of an up-to-date water availability board is important for the people considering back-country hikes in this park. One must consider the rate of flow and the proximity of the source to the trail or campsites. The aesthetic quality of the source is important also. Many people are reluctant to drink from a source that is not "clean looking".

Bacterial and protozoan populations are very important parameters in determining the quality of our water. Gastro-intestinal distress is a common complaint for people visiting exotic areas (yes, even southern Utah). Exposure to different food, water, cultures and bacterial flora are the common causes for "Traveler's Disease, Montezuma's Revenge, or the Texas Two-step". This is a classic example of man's encounter with organisms that are foreign to his own gut populations.

Most general environmental health water programs do not check a water sample for every type of pathogenic organism. An accurate identification program like that would require too much time and money for routine sampling. Instead, the samples are checked for the presence of an "indicator species". In most cases, the particular indicator species is not pathogenic under normal conditions. The indicator species signal the possible contamination of a substance by fecal material.

The two indicator species of fecal contamination that are generally considered for surveillance are the fecal coliforms, i.e., Escherichia coli, and the fecal streptococci, Streptococcus faecalis (Group D Lancefield). Both groups of organisms are found routinely in the gastro-intestinal tracts of vertebrate animals, particularly warm-blooded vertebrates. Most species of the indicator groups survive very poorly once outside of the controlled environment of the gastro-intestinal tract. At best, there is survival but no multiplication, such as with some of the hardier fecal streptococci. Thus, after contamination, water bacterial counts will generally become reduced through the dilution by flowing water and by exposure to a relatively harsh environment. This dissipation is minimized if water flow is very low or ponded.

The Total Coliform parameter is often enumerated in addition to the fecal indicators mentioned above. This is a very general category of classification. All coliforms are not fecal coliforms; however, all fecal coliforms are included under the Total Coliform count. One can determine the approximate population composition of the coliform groups by comparing the counts of the Total Coliform and the Fecal Coliform indices. The fecal coliforms normally comprise but a small percentage of the total coliforms counted.

Methods and Materials

Sampling

Water samples were collected carefully in sterile bottles by VIPs, Steven Nakashima and Cynthia Hall, and by SCA, Marion Pratt. The samples were taken from all major water sources along the Under-the-Rim Trail. Samples were also drawn at least once from sites frequently used by people on special guided walks, SCA trail crews, or concessionaire horse rides.

The samples were collected on Tuesday of each sample period. The samples were packed on ice and shipped by United Parcel Service to the laboratory of the Utah State Division of Health.

Bacteriological Analysis

The state laboratory ran quantitative tests for the Total Coliform, Fecal Coliform, and the Fecal Streptococcus indices as per the methods prescribed by the American Public Health Association (1977). The Multiple Tube Most Probable Number (MPN) statistical technique was used for the Total Coliform (TC) and the Fecal Coliform (FC) analysis. The Fecal Streptococcus (FS) were enumerated by direct colony count on Millipore membrane filters using K-F Streptococcus media.

Two samples were sent to Dr. T.F. Wetzler of the University of Washington, Department of Environmental Health in Seattle, Washington. His laboratory provided a complete identification of all aerobic bacteria in the samples.

Sanitary Surveys

A short sanitary survey was conducted for each sample site. Possible sources of contamination were noted, as well as the presence of animal or human feces near the water source.

Results

Sample Sites

The survey in Bryce Canyon National Park resulted in the analysis of thirty-four samples. The samples were taken from fifteen different sites. The list of sites and the number of times sampled is shown on Table I.

Table I

<u>Sampling Sites and Frequency of Sampling</u>					
<u>Sample Site</u>	<u>Number of Samples</u>				
	1	2	3	4	5
Right Fork Yellow Creek Campsite -----					X
Yellow Creek Group Campsite -----	X				
Yellow Creek at Trail Crossing -----				X	
Sheep Creek Springs -----			X		
Swamp Canyon below Whiteman Connecting Trail -----			X		
Ponderosa Creek Campsite -----				X	
Iron Springs -----			X		
Black Birch Springs -----			X		
Riggs Springs -----		X			
Podunk Springs along the Yovimpa Pass Fire Road --	X				
SCA camp in Yovimpa Pass near Podunk Gate -----	X				
SCA camp at Shaker Springs on Whiteman Bench -----	X				
Water fountain on Peek-A-Boo Trail -----	X				
Jolly Hollow waterfall -----	X				
Mossey Cave -----	X				

Bacteriological Analysis

The results of the bacteriological analysis are recorded on the charts labeled Water Quality Data Sheet. The sample accession log is attached to the report as Appendix I. The actual state health department record forms are attached as Appendix II.

The Total Coliform counts for the samples in this study ranged from zero to 9300 organisms MPN per 100 ml sample.

The Fecal Coliform counts ranged from zero to 75 organisms MPN per 100 ml sample.

The actual colony count for the Fecal Streptococci ranged from zero to 158 organisms per 100 ml sample in this study.

In general, the majority of the sites had Fecal Streptococci and Fecal Coliform counts of less than 25 organisms per 100 ml sample. Counts exceeding this level were found routinely in only three sample sites: Right Fork Yellow Creek Campsite, Yellow Creek at the trail crossing and at the Ponderosa campsite.

The samples taken at the campsite for the Right Fork Yellow Creek had the highest counts for both the Fecal Streptococci and the Fecal Coliform. The next highest was the Yellow Creek samples, followed by the samples from the Ponderosa Creek campsite. Table 2 illustrates the mean bacterial counts for these three sites. The rest of the sites had counts that were essentially negligible.

Table 2

Mean Average Bacterial Counts

Sample Site	Total Coliform MPN/ 100 ml	Fecal Coliform MPN/ 100 ml	Fecal Strep. Count/ 100 ml
Rt. Fork Yellow Creek	972	29	61
Yellow Creek at trail crossing	2410	20	46
Ponderosa Creek Campsite	2550	15	58

WATER QUALITY DATA SHEET

WATER SOURCE: Right Fork Yellow Creek campsite

Date Inspected	6/23/81	7/8/81	7/14/81	7/20/81	8/18/81					
Sample ID Field No.	006	015	033	017	028		Mean Average			
Fecal Coliform MPN/100 ml.	75	43	< 2	--	< 23		29			
Fecal Strep. Count/ 100 ml.	107	158	20	5	17		61			
Ratio FC/FS	0.70	0.27	0.10	--	1.35		0.47			
Total Coliform MPN/100 ml.	1500	>2400	8.	< 23	930		972			

COMMENTS: Water Temperature 53°F 0740 hs. 8/18/81

Campsite is looking very worn from high camper use.

WATER QUALITY DATA SHEET

WATER SOURCE: Yellow Creek Group Campsite

Date Inspected	6/23/81									
Sample ID Field No.	005									
Fecal Coliform MPN/100 ml.	9									
Fecal Strep. Count/ 100 ml.	57									
Ratio FC/FS	0.16									
Total Coliform MPN/100 ml.	240									

COMMENTS:

WATER QUALITY DATA SHEET

WATER SOURCE: Yellow Creek at the trail crossing

Date Inspected	6/23/81	7/8/81	7/20/81	8/18/81						
Sample ID Field No.	004	016	018	029		Mean Average				
Fecal Coliform MPN/100 ml.	23	9	< 23	< 23		20				
Fecal Strep. Count/ 100 ml.	36	137	11	2		46				
Ratio FC/FS	0.64	0.066	2.1			0.42				
Total Coliform MPN/100 ml.	43	9300	150	150						

COMMENTS: Water temperature 52 F 0910 hrs. 8/18/81

WATER QUALITY DATA SHEET

WATER SOURCE: Sheep Creek Spring

Date Inspected	6/23/81	7/20/81	8/18/81							
Sample ID Field No.	003	019	030		Mean Average					
Fecal Coliform MPN/100 ml.	<3	<23	<23		16.33					
Fecal Strep. Count/ 100 ml.	3	5	11		8					
Ratio FC/FS	0	4.6			2					
Total Coliform MPN/100 ml.	43	930	2400							

COMMENTS: Water Temperature 50°F 1120 hrs. 8/18/81
 Spring is located about 1/2 from the Under-the-Rim Trail and from the campsite. Several nice sites are located closer to the spring. The spring is susceptible to contamination when the cattle are driven up the trail to the plateau.

WATER QUALITY DATA SHEET

WATER SOURCE: Swamp Canyon below Whiteman Connecting Trail

Date Inspected	6/24/81	7/20/81	8/18/81						
Sample ID Field No.	007	020	027		Mean Average				
Fecal Coliform MPN/100 ml.	< 3	< 23	< 23		16				
Fecal Strep. Count/ 100 ml.	9	4	11		8				
Ratio FC/FS	0.333	5.75	2.1		2				
Total Coliform MPN/100 ml.	430	1500	2400		1443				

COMMENTS: Water Temperature 53°F 1050 hrs. 8/18/81
Samples taken where the stream crosses the Under-the-Rim Trail below the campsite.

WATER QUALITY DATA SHEET

WATER SOURCE: Ponderosa Campsite- South Fork Ponderosa Creek

Date Inspected	6/24/81	7/8/81	7/14/81	7/20/81	8/18/81					
Sample ID Field No.	009	013	034	022	DRY		Mean Average			
Fecal Coliform MPN/100 ml.	9	9	< 20	< 23			15			
Fecal Strep. Count/ 100 ml.	94	56	50	33			58			
Ratio FC/FS	0.10	0.16	0.40	0.70			0.26			
Total Coliform MPN/100 ml.	> 2400	> 2400	1100	4300			2550			

COMMENTS:

Creek was dry after August 1st.

WATER QUALITY DATA SHEET

WATER SOURCE: Iron Springs

Date Inspected	6/24/81	7/20/81	8/18/81							
Sample ID Field No.	010	023	031		Mean Average					
Fecal Coliform MPN/100 ml.	< 3	< 23	0		8					
Fecal Strep. Count/ 100 ml.	0	5	< 3		2					
Ratio FC/FS	0	4.6			4					
Total Coliform MPN/100 ml.	< 3	230	< 23		86					

COMMENTS: Water Temperature 46°F 0900 hrs. 8/18/81
Spring is susceptible to contamination by trail run-off and by cattle.

WATER QUALITY DATA SHEET

WATER SOURCE: Black Birch Springs

Date Inspected	6/24/81	7/20/81	8/18/81							
Sample ID Field No.	011	024	032		Mean Average					
Fecal Coliform MPN/100 ml.	< 3	< 23			8.7					
Fecal Strep. Count/ 100 ml.	11	37	17		22					
Ratio FC/FS	0.27	0.62			0.4					
Total Coliform MPN/100 ml.	9	390	< 23							

COMMENTS: Water Temperature 49°F 0920 hrs. 8/18/81
Spring is open to contamination from trail run-off and cattle.

WATER QUALITY DATA SHEET

WATER SOURCE: Riggs Spring

Date Inspected	6/23/81	8/4/81								
Sample ID Field No.	001	026								
Fecal Coliform MPN/100 ml.	<3	0								
Fecal Strep. Count/ 100 ml.	2	6								
Ratio FC/FS	0	0								
Total Coliform MPN/100 ml.	43	<23								

COMMENTS: Sample taken as water leaves the cistern and enters the watertroughs.

WATER QUALITY DATA SHEET

WATER SOURCE: Podunk Springs along Yovimpa Pass Fire Road

Date Inspected	6/23/81									
Sample ID Field No.	002									
Fecal Coliform MPN/100 ml.	<3									
Fecal Strep. Count/ 100 ml.	4									
Ratio FC/FS	00									
Total Coliform MPN/100 ml.	430									

COMMENTS: Spring located in rock cistern about 40 feet west of the fire road and 1/3 mile north of the Yovimpa Pass campsite. Signs of animal use- deer and cougar prints. Cattle were seen in the area on August 28, 1981 within the Park boundary.

WATER QUALITY DATA SHEET

WATER SOURCE: SCA Spring in Yovimpa Pass near Podunk Gate

Date Inspected	7/8/81									
Sample ID Field No.	12									
Fecal Coliform MPN/100 ml.	<3									
Fecal Strep. Count/ 100 ml.	<3									
Ratio FC/FS										
Total Coliform MPN/100 ml.	4									

COMMENTS: Spring redeveloped by the SCA group in early July, 1981. They used a well point and a rock cairn. No roads or trails above the spring.

WATER QUALITY DATA SHEET

WATER SOURCE: Shaker Springs - SCA Camp Whiteman Bench

Date Inspected	8/4/81									
Sample ID Field No.	025									
Fecal Coliform MPN/100 ml.	0									
Fecal Strep. Count/ 100 ml.	3									
Ratio FC/FS	0									
Total Coliform MPN/100 ml.	<23									

COMMENTS: Spring redeveloped by the SCA group in August, 1981.

WATER QUALITY DATA SHEET

WATER SOURCE: Peek-a-boo Loop Trail Public Water Fountain

Date Inspected	7/20/81									
Sample ID Field No.	021									
Fecal Coliform MPN/100 ml.	-									
Fecal Strep. Count/ 100 ml.	0									
Ratio FC/FS										
Total Coliform MPN/100 ml.	<23									

COMMENTS: Water piped to the fountain from a source located under the rim beneath Bryce Point.

WATER QUALITY DATA SHEET

WATER SOURCE: Jolley Hollow

Date Inspected	6/24/81									
Sample ID Field No.	008									
Fecal Coliform MPN/100 ml.	<3									
Fecal Strep. Count/ 100 ml.	11									
Ratio FC/FS	0									
Total Coliform MPN/100 ml.	75									

COMMENTS: Sample taken from the waterfall immediately below Jolly Hollow.

WATER QUALITY DATA SHEET

WATER SOURCE: Mossy Cave

Date Inspected	7/8/81									
Sample ID Field No.	014									
Fecal Coliform MPN/100 ml.	<3									
Fecal Strep. Count/ 100 ml.	<3									
Ratio FC/FS										
Total Coliform MPN/100 ml.	11									

COMMENTS: Samples taken as water falls from source in the ceiling.

Water Availability

The following list describes the water availability for the campsites along the Under-the-Rim Trail. There was no near-by water supply unless indicated by comments. The observations for water availability were made from approximately June 1st through August 28th, 1981.

Site Location	Water Availability
Rt. Fork Yellow Creek	Good flow continuously
Yellow Creek Group Site	Good flow continuously
Yellow Creek campsite	Good flow continuously
Sheep Creek	<u>Dry at camp</u> - Good flow continuously at Sheep Cr. Springs- 1/2 mile East.
Rt. Fork Swamp Canyon	<u>Dry at camp</u> - Good flow continuously 1/2 mile up the Swamp Canyon Connecting Trail.
Swamp Canyon	<u>Dry at camp</u> - Very low but continuous flow just below the campsite, North along the Under-the-Rim Tr.
Natural Bridge	<u>Dry at camp</u> on June 17th.
Agua Canyon	<u>Dry at camp</u> on June 17th.
Ponderosa Creek campsite	Good flow at camp. <u>Dry after August 1st.</u>
Black Birch Canyon	<u>Dry at camp</u> - Iron Spring and Birch Spring had low but continuous flows throughout the summer.
Corral Hollow	<u>Dry at camp</u> by May 26. Very sporadic flow following late summer thunderstorms.
Riggs Springs	Good flow continuously.
Yovimpa Pass	Low sporadic flow from near the pumphouse by May 26th.

Discussion

Sanitary Significance

The results of the water quality survey are very reassuring in many ways. Many of the sites had little to no evidence of contamination by fecal material. Those sites exhibiting bacterial counts did not show grossly high levels of bacteria.

All of the samples had Fecal Coliform (FC) counts much lower than the bathing beach standards of 200 FC/ 100 ml as recommended by the National Advisory Committee on Water Quality (Geldrich, 1972). The samples also did not surpass the 100 FC/ 100ml bathing beach standards set by the Seattle- King County Department of Public Health in Seattle, Washington.

It is important to remember that these are just standards for bathing beaches. The standards do not guarantee that pathogens will be present only when the bacterial counts surpass the standards. Still, the two samples run at the University of Washington did not show the presence of any pathogenic bacteria at either the Ponderosa Creek campsite or at the Right Fork Yellow Creek camp.

There have been no standards set for potable non-treated sources (streams and springs). Most modern health departments require that the water be drawn from an approved source, such as a drilled well. Open springs and streams are not normally considered approved sources for permanent structures. They are often too susceptible to contamination. It was nice to see that the FC comprised a very small percentage of the total coliforms counted in our samples. This indicates that little contamination has occurred by fecal material.

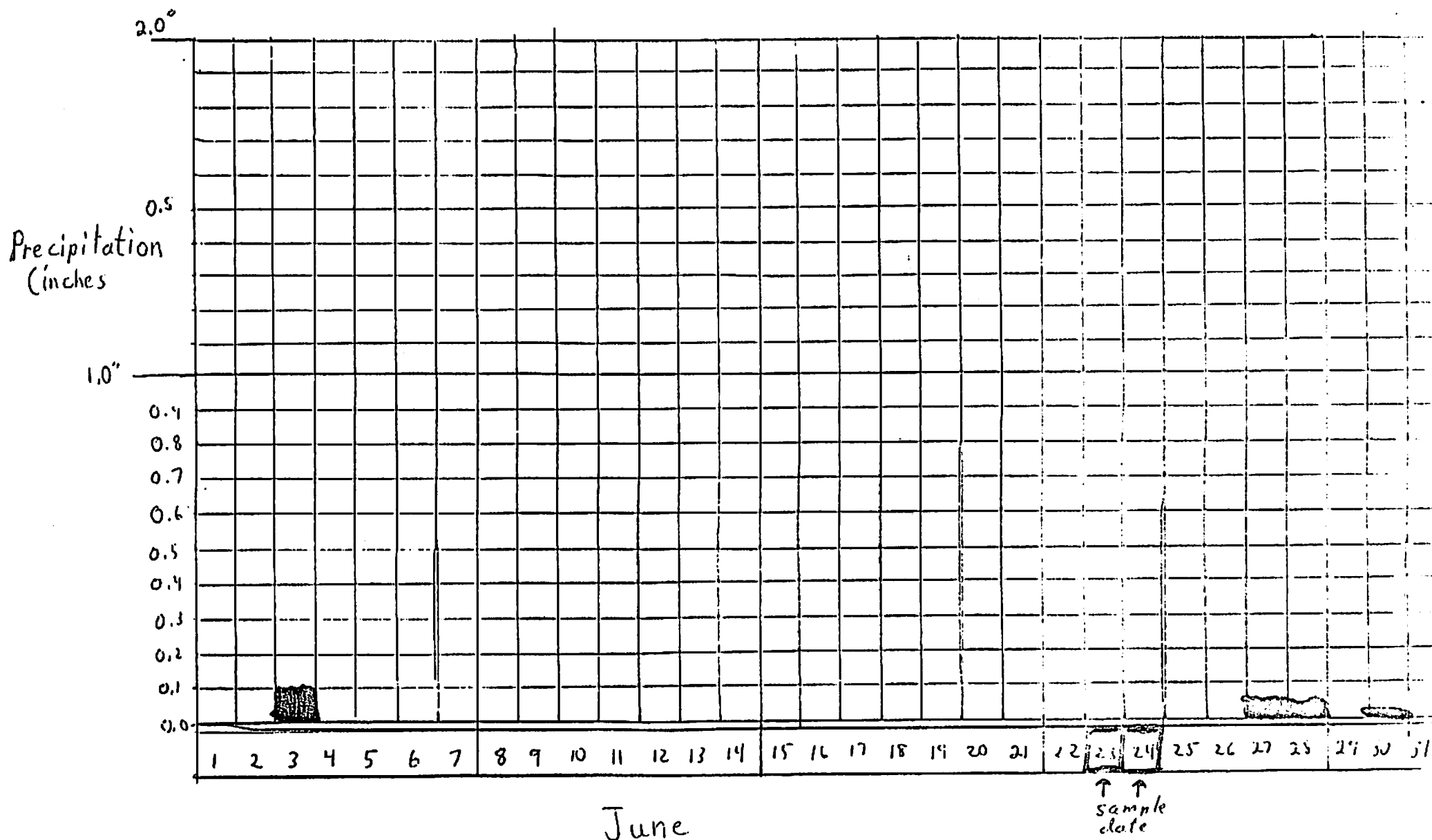
Comparison of Water Quality Between Springs and Stream Sources

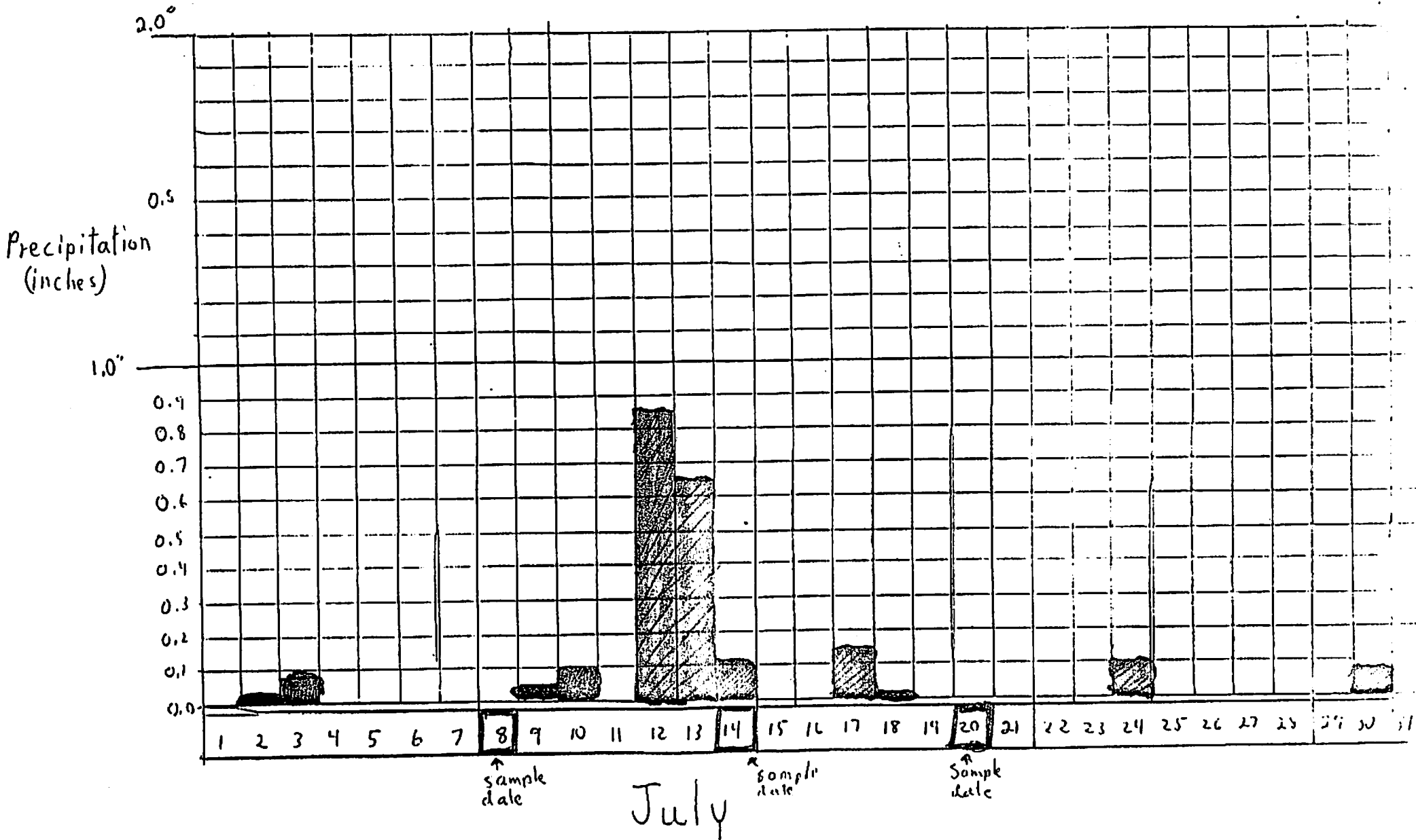
It is interesting to note that the water quality of the streams was different than the springs. The results for the streams seemed to change during the sample period, while the spring data remained somewhat consistent. The springs also had better water quality when compared to the streams.

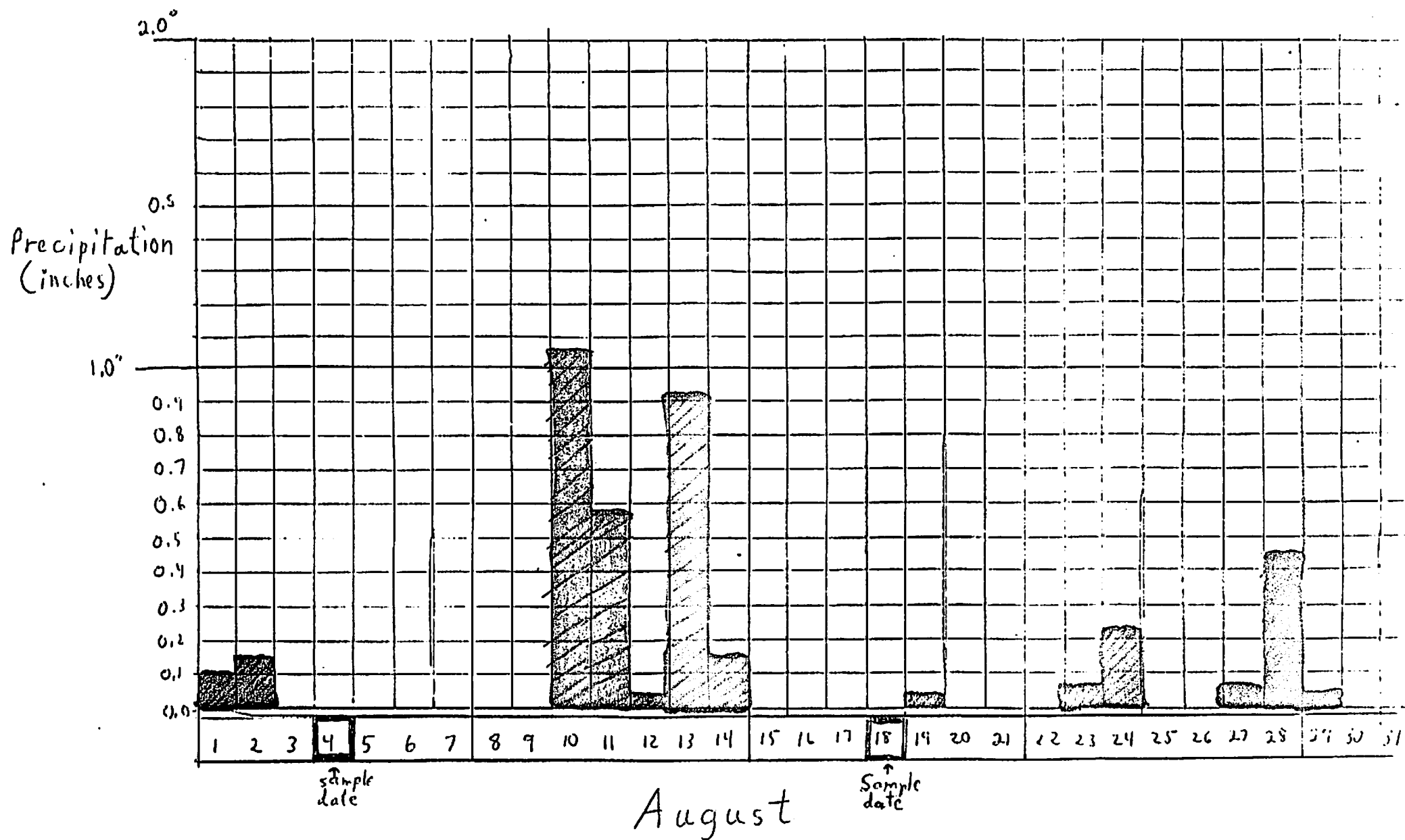
The primary sites with elevated bacterial counts, as discussed earlier, were Right Fork Yellow Creek, Yellow Creek at the trail crossing, and at the Ponderosa Creek campsite. Right Fork Yellow Creek (RFYC) was the only site with high FC counts. The other two sites had elevated FS counts but fairly low FC counts. Geldrich (1976) says that even though FS can be used as fecal indicators, some species (*S. faecalis* var. *liquifaciens*) may be long living in a free environment and even considered ubiquitous. Therefore FS counts less than 100 should be regarded lightly since our test do not distinguish *S. faecalis* var. *liquifaciens* from the other fecal streps. This is one reason why there are no sanitary standards based upon the fecal streptococci.

Fecal coliforms are not ubiquitous in nature and do denote fecal contamination by some source. Taking this into account, the samples at the Yellow Creek and Ponderosa sites do not appear out of line with the other samples that had low FC counts, despite the higher FS counts.

RFYC had elevated fecal coliform for only the first two samples. This may be explained by referring to the rainfall tables for the months of June, July, and August. Prior to the June 23rd and July 8th sample dates, we had experienced very little rain- less than 0.35 inches in a 40 day period. Samples taken on both of those dates had higher FC and FS counts than samples taken later in the study. Any contamination of the water sources during this dry period would have had to been by direct contact, since there was no over-the-surface run-off into the water.







Immediately following the July 8th sampling, the park received 1.65 inches of rain within five days. The majority of the rain (1.5 inches) fell in the two days proceeding the sampling on July 14th. Very little of the water soaks into the soil during such a heavy downpour. Most of the water rapidly runs off into the drainages. This rapid run-off could serve to flush much of the contaminants out of the park drainages and well past our sampling sites. This point is reinforced by looking at the bacterial counts for RFYC.

The RFYC bacterial counts for the indicator species are substantially lower on July 14th than those for samples taken earlier in the study. The indicator counts seem to stabilize at a lower level for the duration of the study. This phenomenon was seen in the Yellow Creek samples but not at the Ponderosa or Swamp Canyon sites. The differences between the stream sites may be reflecting the differences in campsite usage. Both Yellow Creek and RFYC had much higher levels of use than the Ponderosa and Swamp Canyon site during the months of June and July.

The spring sources did not reflect any changes in bacterial count after heavy rainfall. Sheep Creek Springs, Riggs Spring, Iron and Birch Springs were all sampled at least twice and did not show much variation in water quality or flow.

Springs are less susceptible to contamination than the streams. They are reasonably protected by overlying rock until the water daylights at the sample point. The water flow does not vary much because the source is from buried aquifers. These aquifers are recharged very little by the rains of our summer storms. Most aquifer recharge is a result of the snow melt during the winter and spring.

Sources of Contamination

It is possible to determine the source of fecal contamination by the comparison of the bacterial counts for the indicator organisms (Geldrich, 1976). The indicator in this system is the ratio of FC: FS. Human feces and samples of domestic sewage exhibit a FC:FS ratio of greater than 4.0. The FC:FS ratio for all other animals is less than 0.7. This applies to farm animals, domestic pets, and most important in this case- wild animals.

The FC:FS ratios for all samples sites compare favorably with Geldrich for run-off water from rural watersheds in Ohio and Vermont. It appears that the probable source of fecal indicators is by wild animals. The ratios derived from the higher bacterial counts at Right Fork Yellow Creek indicate that humans are not the major source of contamination there. However, I am sure that humans contribute heavily to the waste load in that drainage.

It should be noted here that no testing was undertaken to determine the presence of the protozoan, *Giardia lamblia*. The large sample sizes (1000 gallons) and the additional cost prohibited this activity in our study. The presence or absence of the organism can not be abstracted from the data provided in this study.

Conversations with Craig Nichols of the Utah State Division of Health, Epidemiology Section confirms that outbreaks of giardiasis have been occurring in southwest Utah. He felt that all surface waters should be regarded as having giardia present. He recommends a ten minute boil at high elevations or the use of an iodine purifying compound.

Conclusions and Recommendations

It appears that the campsites on the Under-the-Rim Trail do not receive heavy enough use to pose a severe threat of contamination to the back-country waters of Bryce Canyon National Park. Repeated sampling indicates that the waters are presently of high quality bacteriologically. No pathogens were isolated and the levels of fecal indicators were low. This does not mean that we can afford to relax our standards in regards to the visitation of our back-country. On the contrary, greater efforts should be taken to ensure the protection of the water quality at Bryce Canyon National Park:

- 1) Campsites should be designated no closer than fifty feet from the water sources.
- 2) Signs reminding campers to purify the water should be posted along the creeks at the campsites.
- 3) It would be appropriate to do a giardia sampling program, perhaps in conjunction with the U.S. Forest Service and the Utah State Division of Health. Fecal samples of animals can be submitted to the lab for analysis. This is much less cumbersome than 1000 gallons of water. Fecal specimens could be taken from muskrats, beavers, and deer killed in the park or out by Tropic Reservoir.
- 4) Gravelled wash pits could be used at the heavy-use sites for dish-washing and personal hygiene. This would reduce that amount of soap and food getting into the streams (I hate finding old spaghetti clinging the streambeds).
- 5) Iron and Birch Springs could use protection from trail run-off and from the periodic cattle infestations. This could be accomplished by proper contouring of the trail above the springs and by fencing (no cyclone fencing please).

6) Sheep Creek campsite could be moved closer to Sheep Creek Springs. There are several nice sites after you cross the creek bed to the East. It would provide a little more isolation from the main trail and would move the camp closer to a continuous water supply.

7) Both the Right Fork Yellow Creek and the Yellow Creek Group sites are beginning to show quite a bit of wear and tear. You may want to rest these two sites and relocate a little further away from the creeks. The Right Fork campsite could be moved to the area where the trail crosses the creek.

Bibliography

- American Public Health Association 1977. Standard Methods for the Analysis of Water and Wastewater, 14th ed. New York.
- Geldreich, E.E., 1966. Sanitary Significance of Fecal Coliforms in the Environment. Water Pollution Control Research Series Publication No. WP-20-3. U.S. Dept. of the Interior, Federal Water Pollution Control Administration.
- Geldreich, E.E., 1968. The Bacteriological Aspects of Stormwater Pollution. Journal of Water Pollution Control Federation 40 (11): 1861-1872.
- Geldreich, E.E., 1972. Buffalo Lake Recreational Water Quality: A Study in Bacteriological Data Interpretation in Water Research. Pergamon Press, Gr. Britain. Vol. 6, pp. 913- 924.
- Geldreich, E.E., 1976. Fecal Coliform and Fecal Streptococcus Density Relationships in Waste Discharges and Receiving Waters. CRC Critical Reviews in Environmental Control, pp. 349- 369.
- Marine, I. Wendell, 1963. Ground-water Resources of the Bryce Canyon National Park area, Utah. U.S. Department of the Interior, Geological Survey Water-Supply Paper 1475-M. U.S. Government Printing Office, Washington D.C.