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The Bacterial and Chemical Inputs to
Zion National Park

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Abstract

Three major streams flow through Zion National Park: the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek. The water quality of these three streams was studied during the summer of 1977. Bacterial indicators and the background water chemistry were measured.

Given the location and frequency of the recreational use of the Park, emphasis was placed on the bacterial concentrations of the North Fork. Water samples were taken both inside and outside the Park to determine bacterial inputs of surrounding areas. It is shown that some upstream uses on private land do have an impact on water quality in the North Fork.

Introduction

Zion National Park is drained by three major streams, the North and East Fork (of the Virgin River) and LaVerkin Creek. The headwaters of all three streams are located outside the Park. Because the water quality of these streams has been determined in part by land use outside the Park, this study was designed to monitor the water quality entering the Park, and, when possible, to study key areas of water quality degradation outside the Park. The study includes the analysis of both the water chemistry and bacteriology of the three major streams. Emphasis was given to the North Fork because of its heavier recreational use.

Study objectives

- 1) To determine the bacterial water quality of the North Fork as it enters Zion National Park.
- 2) To evaluate land use practices outside the Park as they may influence the water quality of the North Fork.
- 3) To establish water chemistry baseline data for the North Fork, East Fork and LaVerkin Creek during summer low flows.
- 4) To present conclusions and recommendations.

Previous Investigations

Nonpoint sources of pollution are receiving increased attention in wildland water quality management. One of the primary sources of non-point bacterial pollution comes from domestic animal grazing. Cattle and sheep grazing contribute to increases in bacterial concentrations of mountain streams; however, the magnitude of this increase varies greatly.

One of the primary factors affecting bacterial inputs is the proximity of the grazing animal to the live stream channel. Kunkle (1970) found that increases in bacterial levels of mountain streams were directly related to the accessibility of cattle to the stream. Similar results were found in studies by Morrison and Fair (1966) and Kunkle and Meiman (1967).

In addition to the accessibility factor, the simple presence of grazing animals influences wildland water quality. Darling and Coltharp (1973) found significant increases in bacteria concentration in streams directly downstream from cattle and sheep grazing. Skinner et al. (1972) showed a strong correlation between grazing periods and increased bacterial numbers within high mountain watersheds.

There seems little question that grazing does have an impact on wildland water quality; however, there are other factors to be considered. First, Watler and Bottman (1967), and Stuart et al. (1971) have shown that wildlife can also cause increases in stream bacteria levels.

Second, Mack (1974) has demonstrated that bacteria can survive and even multiply in natural waters. This factor complicates the accurate measurement of bacterial inputs--regardless of the nonpoint source.

Third, Buckhouse (1975) showed that bacterial life spans can be greatly influenced by the conditions of cattle feces. If the feces are allowed to dry quickly, the associated bacteria become encased within a protective media and may survive there for several years. These all add to the complexity of evaluating the impact of grazing on wildland water quality.

In addition to the above considerations, some bacterial indicators are better than others for monitoring the impact of domestic animal wastes on water quality. Kunkle (1977) used total coliform (TC), fecal streptococci (FS), enterococci and fecal coliform (FC) as the primary indicator organisms. Using a controlled environment, Kunkle found the fecal coliforms to be the most responsive and accurate measurement of cattle feces contamination of wildland waters.

Sampling Methods

During the summer of 1977 three streams were sampled. Each has headwaters outside Zion National Park and each represents a major surface water resource for the Park. This section discusses the study areas and reasons for their selection, the parameters measured, the sampling sites, the equipment used, and the analysis of data.

Study area

Figure 1 shows the location of Zion National Park with respect to the three drainage basins. The area of each of these watersheds is given in Table 1.

Table 1. Drainage basin areas for the North Fork and East Fork of the Virgin River and LaVerkin Creek.

Drainage basin	Area (miles ²)
North Fork	328
East Fork	365
LaVerkin Creek	41

The southwestern section of the Park shows no drainage network. This section has not yet been studied for water quality. The area consists primarily of ephemeral streams with their headwaters located totally within the Park boundaries.

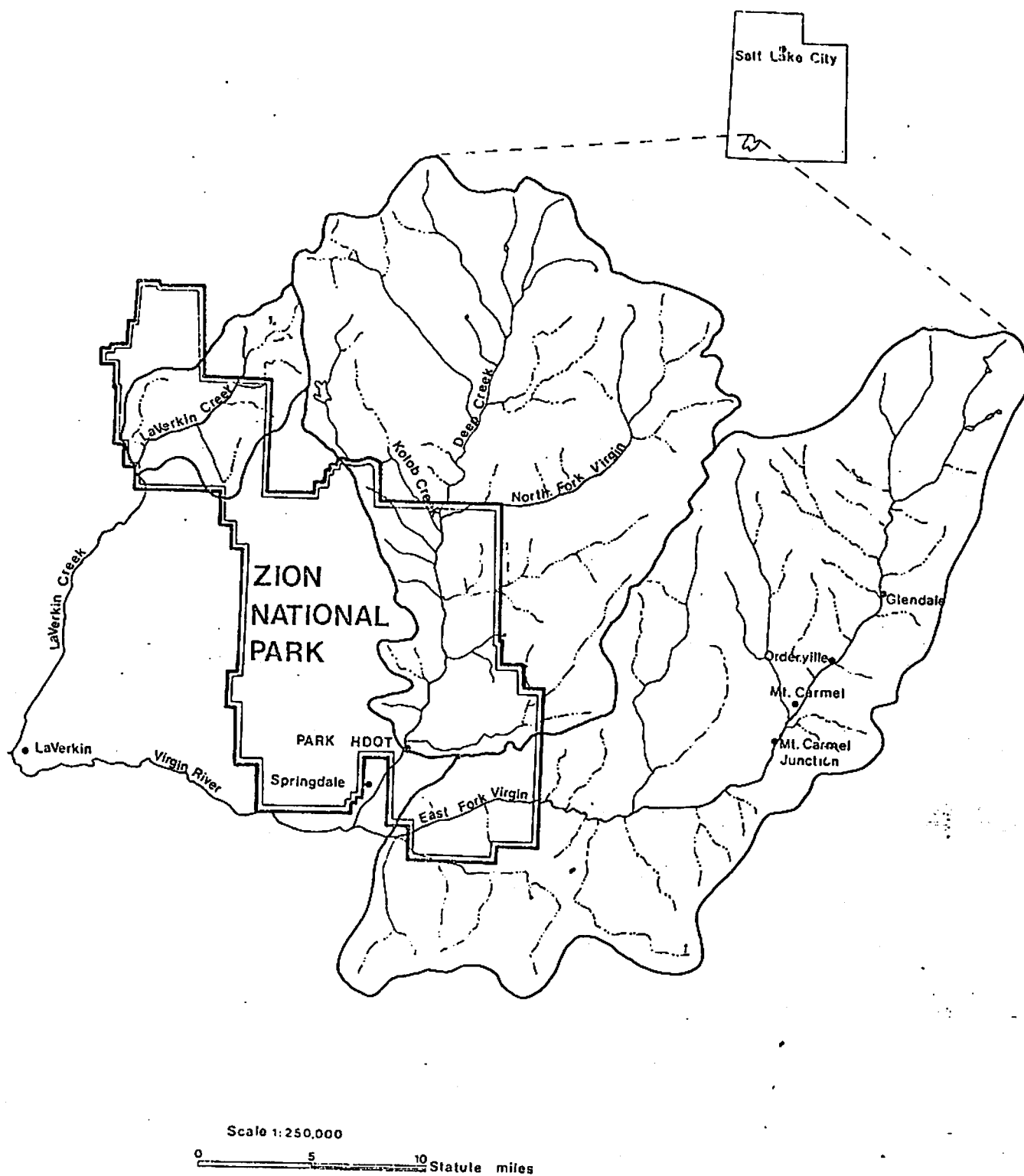


Figure 1. The three major drainage basins of Zion National Park: the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek.

North Fork Watershed

The North Fork watershed receives the heaviest visitor use of the three drainages. This visitor use is restricted to the narrow canyon bottom and consists primarily of sightseeing, camping, and stream channel hiking. Flash flood threats and low water temperatures often restrict recreational water use to mid and late summer periods. These periods usually coincide with the periods of grazing use upstream of the park boundary.

This watershed represents a mosaic of land ownerships (Table 2). Private lands total 65 percent of the watershed, all of which lie upstream from Zion National Park. The most frequent land uses include cattle grazing, summer homes, and private hunting clubs.

This study measured the impact of cattle grazing on the water quality of the North Fork. Two sampling sites were located on the North Fork, one at the park boundary and another 2.5 miles upstream (Figure 2). The cattle grazing within this 2.5 mile reach is confined to narrow pasture lands adjacent to the North Fork. The cattle have free access to the stream.

Table 2. Land ownership of the North Fork of the Virgin River above the Zion National Park Headquarters (BLM, 1975).

	Percent of total area	Mi ²
Private Land	65	236
State Land	3	10
Federal Land		
National Park Service	21	78
Bureau of Land Management	9	32
U.S. Forest Service	2	8
TOTAL	100	364

East Fork Watershed

From a water quality perspective, the East Fork is the most complex of the three drainages. As can be seen from Figure 1, the drainage basin encompasses several small communities. These communities and their associated agricultural and livestock holdings are adjacent to the East Fork of the Virgin River. After passing through these communities, the East Fork flows through the most primitive and inaccessible section of the Park, Parunuweap Canyon. Thus, the drainage basin receives heavier use outside the Park than within the Park.

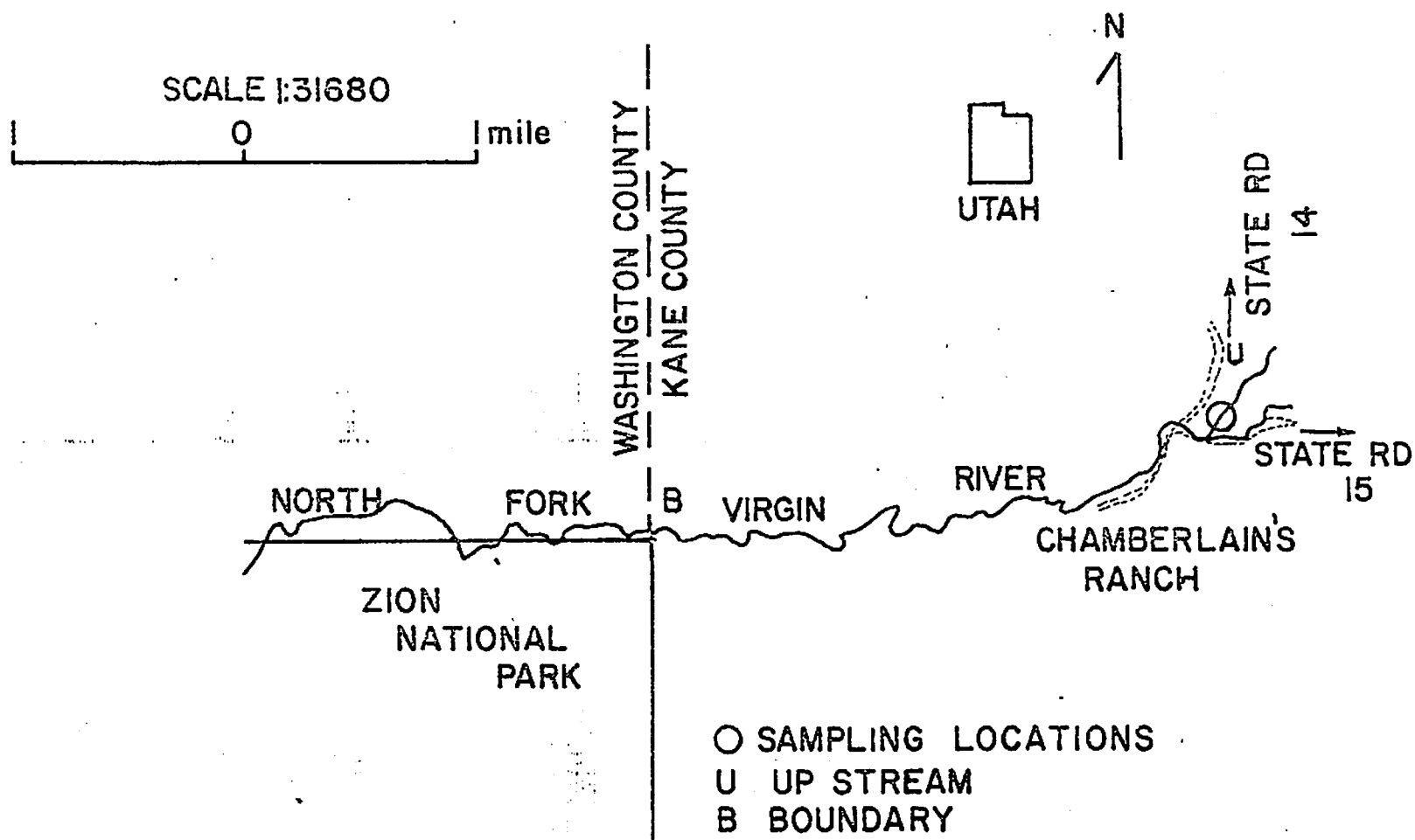


Figure 2. The location of the upstream (U) and boundary (B) sampling sites on the North Fork of the Virgin River.

LaVerkin Watershed

✓ Like the North Fork, LaVerkin Creek drains private lands before entering National Park Service land. Here the private land use consists of cattle and sheep grazing. Grazing occurs between April and October and as many as 300 head of cattle and 600 head of sheep may be grazing per season within the basin headwaters (Gree^{nee} 1977).

This area of the Park is referred to as the Kolob Section. Visitor use is light, compared to the North Fork section of the Park. Also, unlike the North Fork, visitors are not restricted to the active stream channel; they have much greater flexibility in selecting areas of use.

Sampling sites

Five sites were sampled: three on the North Fork and one each on the East Fork and LaVerkin Creek. The East Fork, LaVerkin Creek, and one of the North Fork sampling sites were located within Zion National Park. These sites were designed to measure the water chemistry and bacteria levels of the water resources within the Park. The remaining two sites on the North Fork were located outside the Park and were chosen to measure the bacterial inputs into the Park from upstream use. These two sites were located above and below specific land uses, as shown in Figure 3.

The parameters measured

Three bacterial indicators were measured: total coliforms (TC), fecal coliforms (FC), and fecal streptococci (FS). The physical parameters

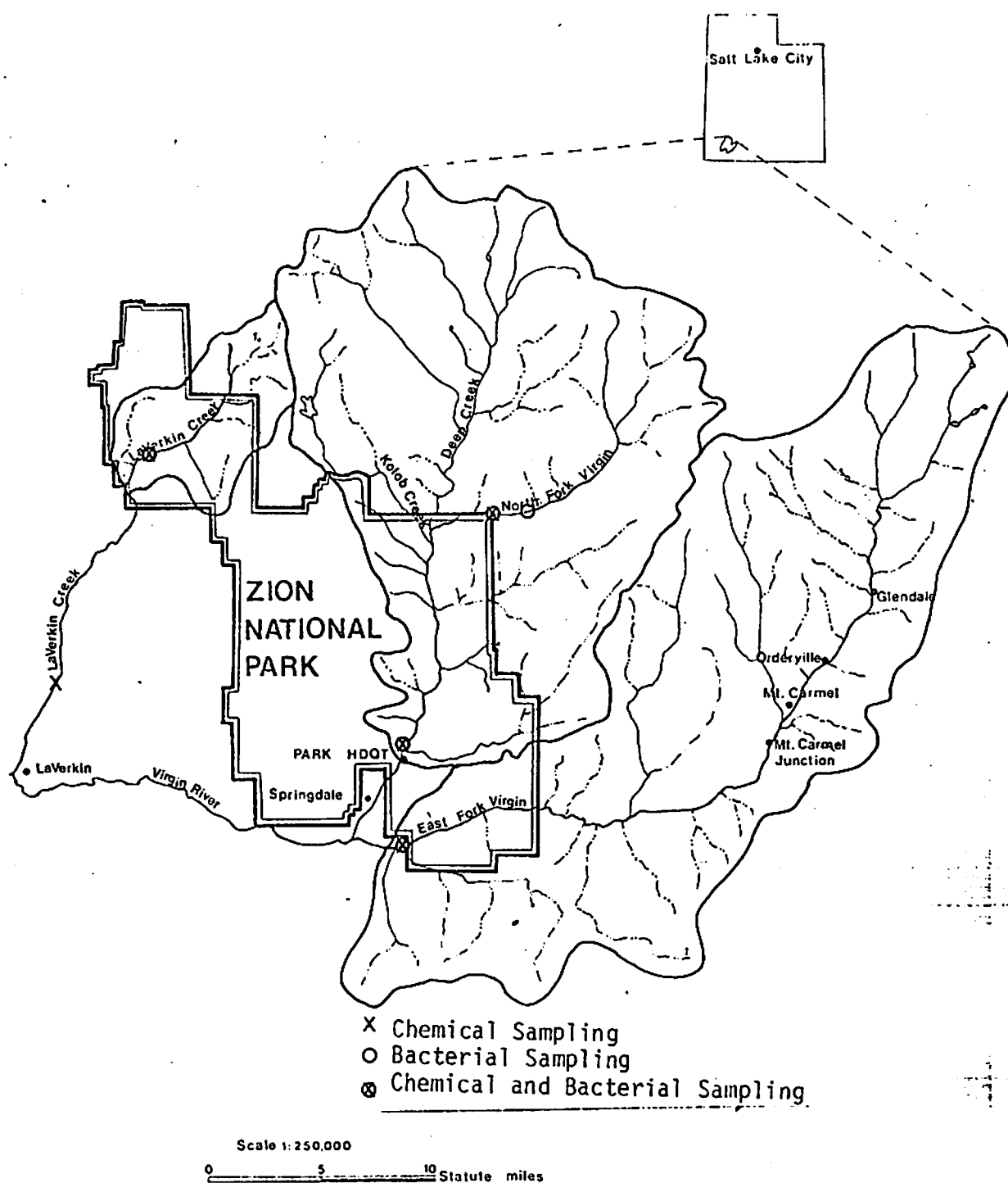


Figure 3. The chemical and bacterial samplings sites for the North Fork, East Fork, and LaVerkin Creek.

included turbidity and total dissolved solids. A broad spectrum of chemical elements were analyzed in addition to conductivity, alkalinity and total hardness.

Equipment used

The membrane filter technique was used for all bacterial analysis. Incubators, sample bags, filter holders, filter papers and procedures were used in accordance with Standard Methods 14th Edition (1976). M-FC and M-Endo growth mediums were taken from prepared ampules and used for the FC and TC incubations, respectively. M-enterococcus agar was used in the incubation of the FS.

Analysis of data

The bacterial samples were collected between 9:00 a.m. and 12:00 noon and were processed at the Park headquarters within 12 hours after collection. Colony identification and plate count methods were followed as outlined in Standard Methods (1976). Standard blanks were taken of the buffer water, filter holders, filter pads, and petri dishes.

One sample was taken at each site. From this sample, three replicates were taken for each of the bacterial indicators. This was done to determine the proper sample volume necessary to achieve the optimum plate count (Standard Methods 1976).

The chemical analyses, including conductivity and turbidity, were performed at Ford Chemical Laboratory in Salt Lake City. These samples were iced during transport and were delivered to Ford Laboratory within 24 hours after their collection.

Results and Discussion

Bacterial results

The results of the analysis for the three stations on the North Fork are given in Tables 3a, b, and c. For all three tables, bacterial concentrations are given for the boundary, the upstream and the head-quarter locations. The total and fecal coliform concentrations measured at the upstream station were greater than the concentrations measured at the headquarters station (Table 3a and 3b). Table 3c shows a similar trend for the fecal strep concentrations.

Table 4 gives the mean concentration of the three bacterial indicators for the upstream and boundary stations. The percent increase in bacterial concentrations was then calculated using these means. The TC increase was the largest, 526 percent, and the FS increase was the lowest, 216 percent.

A group comparison of the mean bacterial concentrations was calculated for the upstream and boundary stations. This analysis indicates that the bacterial concentrations at the boundary station were greater than the bacterial concentrations at the upstream station. The concentration means for the two stations were found to be significantly different at the 95 percent or higher confidence level (Table 5).

Table 3a. Total coliform concentrations for the upstream, boundary, and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

Date	<u>Bacteria concentrations (colonies/100 ml)</u>		
	Upstream	Boundary	Headquarters
July 27, 1977	1,200	12,000	no sample taken
28	1,600	14,600	10,700
29	120	5,300	no sample taken
30	300	11,300	4,800
31	1,160	5,450	no sample taken
Aug. 1, 1977	2,300	5,400	3,600
2	3,700	4,600	1,800
3	1,800	11,000	3,500
4	2,000	12,800	4,200
Sept. 2, 1977	1,320	10,700	3,800
3	1,100	7,600	3,200
4	1,200	10,300	2,800

Table 3b. Fecal coliform concentrations for the upstream, boundary and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

Date	Bacteria concentrations (colonies/100 ml)		
	Upstream	Boundary	Headquarters
July 27, 1977	0*	400	no sample taken
28	0*	600	0*
29	0*	220	no sample taken
30	100*	200	0*
31	35	1,300	no sample taken
Aug. 1, 1977	90	200	60
2	80	100*	80
3	320	420	120
4	360	460	140
Sept. 2, 1977	20*	1,600	20*
3	80*	1,200	72
4	60	620	63

* The colony count was below the optimum range recommended by the Millipore Company and is thus less reliable than other values.

Table 3c. Fecal streptococcus concentrations for the upstream, boundary and headquarter sampling stations (3 replicates of one sample were analyzed for each date).

Date	<u>Bacteria concentrations (colonies/100 ml)</u>		
	Upstream	Boundary	Headquarters
July 27, 1977	60	500	no sample taken
28	100*	1,000	160
29	80	700	no sample taken
30	100*	400	600
31	120	500	no sample taken
Aug. 1, 1977	520	800	110
2	400	600	200
3	240	700	180
4	280	760	230
Sept. 2, 1977	80*	560	40
3	140	700	160
4	120	720	90*

* The colony count was below the optimum range recommended by the Millipore Company and is thus less reliable than other values.

Table 4. Mean bacteria concentrations with percent increases for the upstream and boundary sampling stations.

Bacteria	Bacteria concentration (colonies/100 ml)		Percent increase
	Upstream	Boundary	
TC	1,480	9,270	526%
FC ¹	127	680	435%
FS	190	600	216%

¹ The sampling dates having "0" bacteria concentrations were not included in the mean calculations for either of the sampling locations.

Table 5. Group comparison of means and associated confidence levels for the upstream and boundary sampling stations.

Bacterial parameter	Degrees of freedom	Computed ¹ t	Table t ² value	at	percent confidence level
Total Coliform	11	7.242	3.106		99%
Fecal Coliform	8	2.707	2.306		95%
Fecal Strep.	11	8.861	3.106		99%

¹ Dixon, Wilfrid J. and Massey, Frank J. 1969. Introduction to Statistical Analysis. McGraw Hill, New York. p. 116.

² Dixon and Massey, p. 464.

The East Fork and LaVerkin Creek were also sampled for bacterial concentrations. Tables 6 and 7 give the bacterial results for these two streams. Samples were taken at three dates at each of the locations. These results are presented as summer baseline data and are not intended to represent trends or absolute concentrations.

Table 6. Bacteria concentrations for the East Fork of the Virgin River as measured near South Park boundary.

Date	<u>Bacteria Concentration (colonies/100ml)</u>		
	TC	FC	FS
July 26, 1977	2,700	620	270
August 2, 1977	2,500	640	400
September 2, 1977	2,300	580	360

Table 7. Bacteria concentrations for LaVerkin Creek, as measured at Lee Pass Trail, 1977.

Date	<u>Bacteria Concentration (colonies/100ml)</u>		
	TC	FC	FS
July 27, 1977	2,120	60	240
August 2, 1977	1,400	360	200
September 3, 1977	1,600	420	280

Bacteria discussion

The large increases in bacterial concentrations over the 2.5 mile reach of the North Fork indicate that the current land use does have an impact on the water quality. The statistical analysis of this report indicates that the two sampling points represent different populations. From bacterial analysis and field observations, the cattle grazing between the upstream and boundary sampling points have the greatest single impact on the water quality of the North Fork as it enters Zion National Park.

Once within the park, the North Fork bacterial concentration becomes diluted by tributary inflows. Previous studies (Maddox, 1977) have shown the bacterial concentrations of Deep Creek and Kolob Creek to be substantially lower than the bacterial concentrations of the North Fork for any given sampling day. This dilution effect accounts for the lower bacterial concentrations for the headquarter station when compared to the boundary concentration.

In 1975, the Utah State Division of Health published its suggested water quality criteria for swimming waters (Table 8). The upstream and boundary bacteria concentrations for both TC and FC exceed these suggested upper limits. The headquarters bacterial concentrations exceed the upper limits for TC, but not for FC. LaVerkin Creek and East Fork also exceed the upper limits for both TC and FC.

Table 8. Water quality standards for swimming waters, Utah State Division of Health (1975).

Standard definition	<u>Standard Number</u>	
	<u>Coliform Density</u> (colony/100ml)	<u>Fecal Coliform Density</u> (colony/100ml)
Monthly mean may not exceed	1000	200
No more than 20% of samples collected in one month may exceed	1000	-
No more than 10% of samples collected in one month may exceed	4000	400
No more than 5% of samples collected in one month may exceed	4000	-

Chemical results

Table 9 gives the chemical analysis for the North Fork. The three samples were taken during the summer months over a three year period. The sampling dates ranged from late spring runoff (May) to early fall. These concentrations suggest that many of the chemical parameters remain relatively constant throughout the sampling periods. This indicates that as flows increase the chemical inputs increase proportionately, thus the concentrations remain relatively constant throughout the sampling periods. This indicates that as flows increase the chemical inputs increase proportionately, thus the concentrations remain relatively constant.

Table 10 gives the recommended upper limits for swimming and fishery waters for several chemical elements. Sodium (as Na) is the only chemical parameter exceeding these limits. This exceedence is true for the three sampling dates. Sodium is common in most wildland waters with concentrations varying both locally and regionally. The human intake limits for sodium vary greatly, but unless the intake exceeds 1000 mg/l (Water Quality Criteria, 1972), there is little concern.

However, fisheries are more susceptible to high sodium concentrations. McKee and Wolfe (1963) have found 10 mg/l concentration to be an acceptable upper limit for most fresh water fish.

Table 11 gives the water chemistry analysis for LaVerkin Creek. Three samples were taken during a single summer season. One sample was taken near the city of LaVerkin, the other two samples were taken within Zion National Park. Between the two sampling locations there are numerous agricultural lands, row crops, pasture lands, fruit trees, and

Table 9. Water quality data for the North Fork of the Virgin River near the Park headquarters.

Water quality parameter	Sample dates		
	Sept. 17, 1975	July 23, 1976	May 16, 1977
Turbidity (JTU)	4.2	20.0	2.00
Conductivity (μ hos/cm)	793.0	820.0	900.0
pH	7.14	7.56	7.81
Total dissolved solids at 180°C. (mg/l)	516.0	535.0	600.0
Alkalinity as CaCO_3 (mg/l)	158.0	234.0	168.0
Aluminum as Al (mg/l)	<0.01	0.070	0.071
Arsenic as As (mg/l)	<0.01	0.008	<0.001
Bicarbonate as HCO_3 (mg/l)	191.49	202.5	204.9
Barium as Ba (mg/l)	<0.01	0.144	0.091
Boron as B (mg/l)	<0.01	<0.001	0.22
Cadmium as Cd (mg/l)	0.002	<0.001	<0.001
Calcium as Ca (mg/l)	55.2	51.2	21.6
Carbonate as CO_3 (mg/l)	<0.01	<0.01	<0.01
Chloride as Cl (mg/l)	88.0	90.0	130.0
Chromium as Cr (Hex) (mg/l)	<0.01	<0.001	<0.001
Cyanide as Cn (mg/l)	<0.01	<0.01	<0.01
Copper as Cu (mg/l)	0.02	0.006	0.007
Fluoride as F (mg/l)	0.13	0.32	0.28
Total Hardness as CaCO_3 (mg/l)	250.0	234.0	230.0
Iron (Total) as Fe (mg/l)	0.15	0.120	0.086
Iron (Filtered) as Fe (mg/l)	0.02	0.100	0.050
Lead as Pb (mg/l)	<0.01	0.005	<0.001
Magnesium as Mg (mg/l)	26.88	25.4	42.24
Manganese as Mn (mg/l)	0.01	0.035	0.034
Mercury as Hg (mg/l)	<0.001	<0.0002	<0.0002
Nitrate as $\text{NO}_3\text{-N}$ (mg/l)	0.04	0.02	0.10
Phosphate as PO_4 (mg/l)	0.100	0.065	0.035
Potassium as K (mg/l)	3.69	3.32	3.14
Selenium as Se (mg/l)	<0.01	0.077	<0.001
Silica as SiO_2 (mg/l)	4.15	9.9	21.5
Silver as Ag (mg/l)	0.007	<0.001	<0.001
Sulfate as SO_4 (mg/l)	85.50	92.0	82.0
Sodium as Na (mg/l)	57.00	73.0	122.50
Zinc as Zn (mg/l)	0.01	0.007	0.042

Table 10. Recommended upper limits of chemical concentrations for swimming and fishery waters (McKee and Wolfe, 1963).

Chemical parameter	Recommended upper limit
Aluminum as Al (mg/l)	0.50
Arsenic as As (mg/l)	0.10
Barium as Ba (mg/l)	5.00
Boron as B (mg/l)	--
Cadmium as Cd (mg/l)	--
Calcium as Ca (mg/l)	1000.00
Chloride as Cl (mg/l)	1500.00
Chromium as Cr (Hex) (mg/l)	5.00
Cyanide as Cn (mg/l)	0.05
Copper as Cu (mg/l)	0.10
Fluoride as F (mg/l)	5.0
Iron (Total) as Fe (mg/l)	0.20
Iron (Filtered) as Fe (mg/l)	--
Lead as Pb (mg/l)	0.10
Magnesium as Mg (mg/l)	100.0
Manganese as Mn (mg/l)	40.0
Mercury as Hg (mg/l)	0.004
Nitrate as NO ₃ -N (mg/l)	4.20
Phosphate as PO ₄ -P (mg/l)	15.00
Potassium as K (mg/l)	50.00
Selenium as Se (mg/l)	2.0
Silica as SiO ₂ (mg/l)	50.0
Silver as Ag (mg/l)	0.033
Sulfate as SO ₄ (mg/l)	500.00
Sodium as Na (mg/l)	10.00
Zinc as Zn (mg/l)	0.10
Conductivity (μmhos/cm at 25°C)	2000.00

Table 11. Water quality data for La Verkin Creek near La Verkin, Utah and at Lee's Pass Trail.

Water quality parameter	Sample location and date		
	LaVerkin	Lee's Pass Trail	
	May 16, 1977	Aug. 5, 1977	Sept. 4, 1977
Turbidity (JTU)	3.0	1.5	2.0
Conductivity (μ mhos/cm)	1,670.0	677.0	655.0
pH	7.62	7.97	7.80
Total dissolved solids at 180°C. (mg/l)	1,105.0	432.0	422.0
Alkalinity as CaCO ₃ (mg/l)	180.0	148.0	152.0
Aluminum as Al (mg/l)	0.043	0.063	0.149
Arsenic as As (mg/l)	<0.001	<0.001	<0.001
Bicarbonate as HCO ₃ (mg/l)	219.6	180.6	185.4
Barium as Ba (mg/l)	0.048	0.063	0.184
Boron as B (mg/l)	0.22	0.15	0.04
Cadmium as Cd (mg/l)	<0.001	<0.001	<0.001
Calcium as Ca (mg/l)	86.4	84.8	80.8
Carbonate as CO ₃ (mg/l)	<0.01	<0.01	<0.01
Chloride as Cl (mg/l)	16.0	8.0	10.0
Chromium as Cr (Hex) (mg/l)	<0.001	<0.001	<0.001
Cyanide as Cn (mg/l)	<0.01	<0.01	<0.01
Copper as Cu (mg/l)	0.005	0.002	0.004
Fluoride as F (mg/l)	0.40	0.20	0.15
Total Hardness as CaCO ₃ (mg/l)	486.0	330.0	336.0
Iron (Total) as Fe (mg/l)	0.096	0.069	0.133
Iron (Filtered) as Fe (mg/l)	0.044	0.040	0.100
Lead as Pb (mg/l)	<0.001	<0.001	<0.001
Magnesium as Mg (mg/l)	64.8	2.3293	32.16
Manganese as Mn (mg/l)	0.027	0.004	0.007
Mercury as Hg (mg/l)	<0.0002	<0.0002	<0.0002
Nitrate as NO ₃ -N (mg/l)	0.36	0.010	<0.01
Phosphate as PO ₄ (mg/l)	0.045	0.010	0.01
Potassium as K (mg/l)	2.93	2.653	3.70
Selenium as Se (mg/l)	<0.001	<0.001	<0.001
Silica as SiO ₂ (mg/l)	26.0	7.0	8.0
Silver as Ag (mg/l)	0.005	0.014	<0.001
Sulfate as SO ₄ (mg/l)	580.0	202.0	194.0
Sodium as Na (mg/l)	143.0	17.10	11.93
Zinc as Zn (mg/l)	0.025	0.006	0.033

grain crops. Conductivity, total dissolved solids, total hardness, magnesium, sulfate and sodium all show marked increases. However, these increases cannot be totally attributed to agricultural use. The different dates of sampling and subsequent flow volumes may have an impact on these water chemistry variations.

With the exception of sodium, the water samples taken within the Park (Lee's Pass Trail) are within the recommended limits shown in Table 10. Sodium again exceeds this limit, but, as stated above, this becomes of concern only to fresh water fisheries. In this case, the LaVerkin Creek samples are only slightly above the recommended limit and would probably have little, if any, impact on the fisheries.

Table 12 gives the water chemistry for the East Fork. The two samples were taken in the summer of 1977 just upstream from the confluence of the East Fork and the North Fork. These results represent the upstream water use of the East Fork by the municipal and agricultural users in Glendale, Orderville, Mt. Carmel and Mt. Carmel Junction. In comparing these data with the recommended limits of Table 10, the sodium concentration once again exceeds the recommended limit.

The water chemistry of the North Fork changes as it flows through the Park. Table 13 illustrates the magnitude of the downstream change for one sampling day. On this particular day, 21 of the 34 chemical parameters increased, 8 remained unchanged, and 5 decreased in concentration. There are numerous variables that may account for these changes, not the least of which is the tributary inflow. The concentrations

Table 12. Water quality data for the East Fork of the Virgin River near the confluence with the North Fork of the Virgin River.

Water quality parameter	Sampling dates	
	May 13, 1977	Aug. 5, 1977
Turbidity (JTU)	2.50	1.6
Conductivity (μ mhos/cm)	600.0	490.0
pH	7.73	8.10
Total Dissolved Solids at 180° C. (mg/l)	400.0	316.0
Alkalinity as CaCO_3 (mg/l)	150.0	148.0
Aluminum as Al (mg/l)	0.025	0.113
Arsenic as As (mg/l)	<0.001	<0.001
Bicarbonate as HCO_3 (mg/l)	183.0	180.6
Barium as Ba (mg/l)	0.038	0.040
Boron as B (mg/l)	0.14	0.17
Cadmium as Cd (mg/l)	<0.001	<0.001
Calcium as Ca (mg/l)	28.0	55.2
Carbonate as CO_3 (mg/l)	<0.01	<0.01
Chloride as Cl (mg/l)	24.0	24.0
Chromium as Cr (Hex) (mg/l)	<0.001	<0.001
Cyanide as Cn (mg/l)	<0.01	<0.01
Copper as Cu (mg/l)	0.003	0.002
Fluoride as F (mg/l)	0.35	0.17
Total Hardness as CaCO_3 (mg/l)	220.0	230.0
Iron (Total) as Fe (mg/l)	0.079	0.125
Iron (Filtered) as Fe (mg/l)	0.050	0.100
Lead as Pb (mg/l)	<0.001	<0.001
Magnesium as Mg (mg/l)	36.0	22.08
Manganese as Mn (mg/l)	0.009	0.007
Mercury as Hg (mg/l)	<0.0002	<0.0002
Nitrate as $\text{NO}_3\text{-N}$ (mg/l)	0.70	0.70
Phosphate as PO_4 (mg/l)	0.045	0.010
Potassium as K (mg/l)	2.97	3.57
Selenium as Se (mg/l)	<0.001	0.003
Silica as SiO_2 (mg/l)	22.0	8.0
Silver as Ag (mg/l)	<0.001	<0.001
Sulfate as SO_4 (mg/l)	97.0	98.0
Sodium as Na (mg/l)	30.30	24.38
Zinc as Zn (mg/l)	0.020	0.008

Table 13. Water chemistry data for the North Fork of the Virgin River as measured at the headquarters and Chamberlain's Ranch, July 23, 1976.

Parameter	Sampling location	
	Chamberlain's Ranch	Gage
Turbidity (JTU)	15.0	20.0
Conductivity (μ mhos/cm)	570.0	820.0
pH	7.60	7.56
Total dissolved solids at 180°C. (mg/l)	370.0	535.0
Alkalinity as CaCO_3 (mg/l)	206.0	234.0
Aluminum as Al (mg/l)	0.065	0.070
Arsenic as As (mg/l)	<0.001	0.008
Bicarbonate as HCO_3 (mg/l)	251.3	202.5
Barium as Ba (mg/l)	0.089	0.144
Boron as B (mg/l)	<0.001	<0.001
Cadmium as Cd (mg/l)	<0.001	<0.001
Calcium as Ca (mg/l)	47.2	51.2
Carbonate as CO_3 (mg/l)	<0.01	<0.01
Chloride as Cl (mg/l)	4.0	90.0
Chromium as Cr (Hex) (mg/l)	<0.001	<0.001
Cyanide as Cn (mg/l)	<0.01	<0.01
Copper as Cu (mg/l)	0.005	0.006
Fluoride as F (mg/l)	0.30	0.32
Total Hardness as CaCO_3 (mg/l)	208.0	234.0
Iron (Total) as Fe (mg/l)	0.110	0.120
Iron (Filtered) as Fe (mg/l)	0.100	0.100
Lead as Pb (mg/l)	<0.001	0.005
Magnesium as Mg (mg/l)	21.6	25.4
Manganese as Mn (mg/l)	0.025	0.035
Mercury as Hg (mg/l)	<0.0002	<0.0002
Nitrate as $\text{NO}_3\text{-N}$ (mg/l)	0.05	0.02
Phosphate as PO_4 (mg/l)	0.035	0.065
Potassium as K (mg/l)	1.62	3.32
Selenium as Se (mg/l)	0.007	0.077
Silica as SiO_2 (mg/l)	15.0	9.9
Silver as Ag (mg/l)	<0.001	<0.001
Sulfate as SO_4 (mg/l)	18.7	92.0
Sodium as Na (mg/l)	18.7	73.0
Zinc as Zn (mg/l)	0.012	0.007

given in Table 13 serve to indicate possible directions of water chemistry changes with respect to time and location. These concentrations offer baseline water chemistry data.

Conclusion and Recommendations

The following conclusions are the result of analyses of samples collected during the summers of 1976 and 1977.

1) The total coliform and fecal coliform concentrations of the North Fork of the Virgin River, the East Fork of the Virgin River, and LaVerkin Creek all exceed the Utah State Division of Health recommended limits for swimming waters.

2) The bacterial concentrations within Zion National Park are influenced more by the uses outside the Park than the uses within the Park.

3) Cattle grazing, adjacent and upstream from the Park, does have an impact on the bacterial concentrations of the North Fork of the Virgin River.

4) Over a 2.5 mile reach of the North Fork of the Virgin River total coliform, fecal coliform and fecal streptococcus increased 526, 435 and 216 percent, respectively. These increases are attributed primarily to cattle grazing within the 2.5 mile reach outside the park.

5) With the exception of sodium, all of the measured chemical element concentrations were within the recommended limits for fresh water fisheries.

6) Because of the bacterial concentrations, recreationists should be made aware of the potential health hazards of human ingestion of the waters of the North Fork, East Fork, and LaVerkin Creek.

Literature Cited

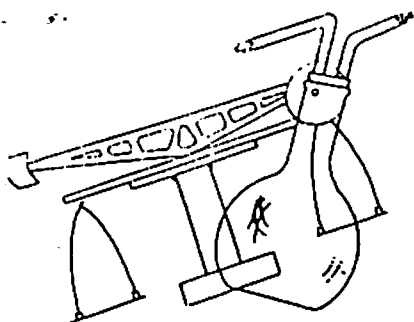
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Appendix A

Chemical analysis of Zion National Park water resources
as analyzed by Ford Chemical Laboratory, Inc.

Salt Lake City, Utah



Ford Chemical

LABORATORY, INC.

Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: October 6, 1975

Name Mr. George Hart

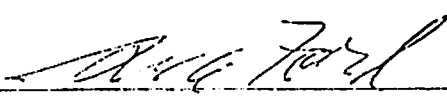
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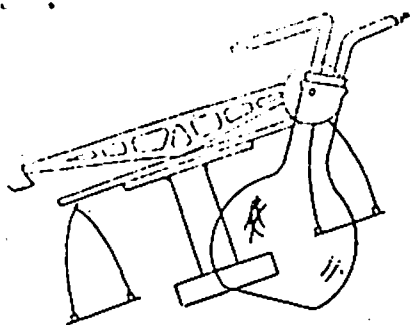
Address Forestry & Outdoor Recreation
Utah State University
Logan, UT 84321

75-4199

Sample Water from North Fork of Virgin River at Highway 89 received
on September 17, 1975.

Turbidity	4.2	ITU	Fluoride as F	0.13	mg/l
Conductivity	793.0	umhos/cm	Total Hardness as CaCO ₃	250.0	mg/l
pH	7.14		Iron (Total) as Fe	0.15	mg/l
Total Dissolved Solids at 180° C.	516.0	mg/l	Iron (Filtered) as Fe	0.02	mg/l
Alkalinity as CaCO ₃	158.0	mg/l	Lead as Pb	<0.01	mg/l
Aluminum as Al	<0.01	mg/l	Magnesium as Mg	26.88	mg/l
Arsenic as As	<0.01	mg/l	Manganese as Mn	0.01	mg/l
Bicarbonate as HCO ₃	191.49	mg/l	Mercury as Hg	<0.001	mg/l
Barium as Ba	<0.01	mg/l	Nitrate as NO ₃ -N	0.04	mg/l
Boron as B	<0.01	mg/l	Phosphate as PO ₄	0.100	mg/l
Cadmium as Cd	0.002	mg/l	Potassium as K	3.69	mg/l
Calcium as Ca	55.2	mg/l	Selenium as Se	<0.01	mg/l
Carbonate as CO ₃	<0.01	mg/l	Silica as SiO ₂	4.15	mg/l
Chloride as Cl	88.0	mg/l	Silver as Ag	0.007	mg/l
Chromium as Cr (Hex)	<0.01	mg/l	Sulfate as SO ₄	95.50	mg/l
Cyanide as Cn	<0.01	mg/l	Sodium as Na	57.00	mg/l
Copper as Cu	0.02	mg/l	Zinc as Zn	0.01	mg/l


Ford Chemical Laboratory, Inc.



Ford Chemical

LABORATORY, INC.

Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

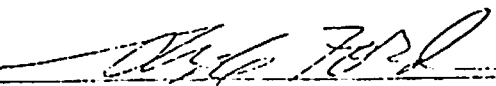
Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

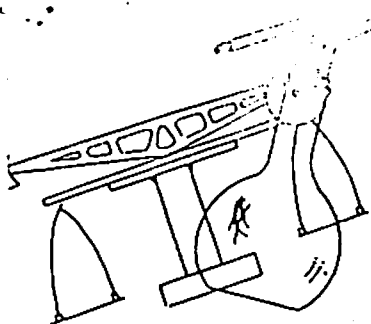
CERTIFICATE OF ANALYSIS

76-5008

Sample Water at North Fork-Virgin River, Chamberlin Ranch. Received on
July 23, 1976 - Zion Park Research:

Turbidity	<u>15.0</u> TU	Fluoride as F	<u>0.30</u> mg/l
Conductivity	<u>570.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>208.0</u> mg/l
pH	<u>7.60</u>	Iron (Total) as Fe	<u>0.110</u> mg/l
Total Dissolved Solids at 180° C.	<u>370.0</u> mg/l	Iron (Filtered) as Fe	<u>0.100</u> mg/l
Alkalinity as CaCO ₃	<u>206.0</u> mg/l	Lead as Pb	<u>< 0.001</u> mg/l
Aluminum as Al	<u>0.065</u> mg/l	Magnesium as Mg	<u>21.6</u> mg/l
Arsenic as As	<u>< 0.001</u> mg/l	Manganese as Mn	<u>0.025</u> mg/l
Bicarbonate as HCO ₃	<u>251.3</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Barium as Ba	<u>0.089</u> mg/l	Nitrate as NO ₃ -N	<u>0.05</u> mg/l
Boron as B	<u>< 0.001</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Potassium as K	<u>1.62</u> mg/l
Calcium as Ca	<u>47.2</u> mg/l	Selenium as Se	<u>0.007</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silica as SiO ₂	<u>15.0</u> mg/l
Chloride as Cl	<u>4.0</u> mg/l	Silver as Ag	<u>< 0.001</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sulfate as SO ₄	<u>34.0</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Sodium as Na	<u>18.7</u> mg/l
Copper as Cu	<u>0.005</u> mg/l	Zinc as Zn	<u>0.012</u> mg/l


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Ford Chemical

LABORATORY, INC.

Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 17, 1976

From Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

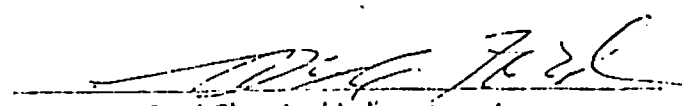
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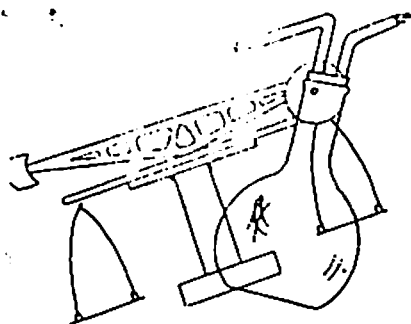
76-5010

Sample Water labeled Deep Creek Received on July 23, 1976, Zion Park

Research: _____

Turbidity	<u>7.5</u> JTU	Fluoride as F	<u>0.27</u> mg/l
Conductivity	<u>630.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>180.0</u> mg/l
pH	<u>7.58</u>	Iron (Total) as Fe	<u>0.110</u> mg/l
Total Dissolved Solids 180° C.	<u>410.0</u> mg/l	Iron (Filtered) as Fe	<u>0.100</u> mg/l
Alkalinity as CaCO ₃	<u>138.0</u> mg/l	Lead as Pb	<u><0.001</u> mg/l
Aluminum as Al	<u>0.130</u> mg/l	Magnesium as Mg	<u>15.84</u> mg/l
Arsenic as As	<u><0.001</u> mg/l	Manganese as Mn	<u>0.038</u> mg/l
Bicarbonate as HCO ₃	<u>168.4</u> mg/l	Mercury as Hg	<u><0.0002</u> mg/l
Barium as Ba	<u>0.089</u> mg/l	Nitrate as NO ₃ -N	<u><0.01</u> mg/l
Boron as B	<u><0.001</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	<u>0.002</u> mg/l	Potassium as K	<u>1.58</u> mg/l
Calcium as Ca	<u>45.6</u> mg/l	Selenium as Se	<u>0.006</u> mg/l
Carbonate as CO ₃	<u><0.01</u> mg/l	Silica as SiO ₂	<u>0.90</u> mg/l
Chloride as Cl	<u>4.0</u> mg/l	Silver as Ag	<u><0.001</u> mg/l
Chromium as Cr (Hex)	<u><0.001</u> mg/l	Sulfate as SO ₄	<u>130.0</u> mg/l
Cyanide as Cn	<u><0.01</u> mg/l	Sodium as Na	<u>45.0</u> mg/l
Copper as Cu	<u>0.005</u> mg/l	Zinc as Zn	<u>0.008</u> mg/l


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PHONE 485-5761

Date: August 17, 1976

Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, UT 84321

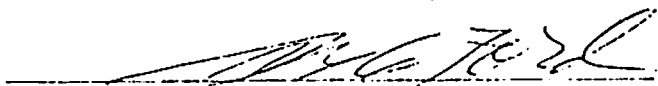
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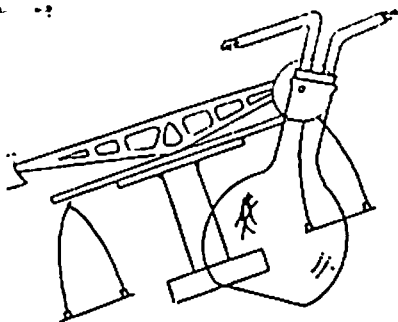
76-5009

Sample Water Labeled Kolob Creek Received on July 23, 1976-Zion Park

Research: _____

Turbidity	<u>8.0</u> JTU	Fluoride as F	<u>0.30</u> mg/l
Conductivity	<u>480.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>190.0</u> mg/l
pH	<u>7.70</u>	Iron (Total) as Fe	<u>0.080</u> mg/l
Total Dissolved Solids at 180° C.	<u>315.0</u> mg/l	Iron (Filtered) as Fe	<u>0.050</u> mg/l
Alkalinity as CaCO ₃	<u>158.0</u> mg/l	Lead as Pb	<u><0.001</u> mg/l
Aluminum as Al	<u>0.060</u> mg/l	Magnesium as Mg	<u>15.36</u> mg/l
Arsenic as As	<u><0.001</u> mg/l	Manganese as Mn	<u>0.030</u> mg/l
Bicarbonate as HCO ₃	<u>192.8</u> mg/l	Mercury as Hg	<u><0.0002</u> mg/l
Barium as Ba	<u>0.099</u> mg/l	Nitrate as NO ₃ -N	<u>0.04</u> mg/l
Boron as B	<u><0.001</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	<u><0.001</u> mg/l	Potassium as K	<u>1.72</u> mg/l
Calcium as Ca	<u>50.4</u> mg/l	Selenium as Se	<u><0.001</u> mg/l
Carbonate as CO ₃	<u><0.01</u> mg/l	Silica as SiO ₂	<u>0.40</u> mg/l
Chloride as Cl	<u>4.0</u> mg/l	Silver as Ag	<u><0.001</u> mg/l
Chromium as Cr (Hex)	<u><0.001</u> mg/l	Sulfate as SO ₄	<u>45.0</u> mg/l
Cyanide as Cn	<u><0.01</u> mg/l	Sodium as Na	<u>10.0</u> mg/l
Copper as Cu	<u>0.011</u> mg/l	Zinc as Zn	<u>0.003</u> mg/l


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36

Date: August 17, 1976

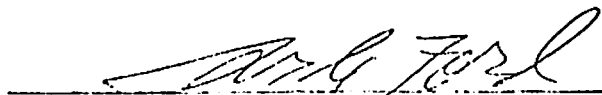
Name Utah State University
ATTN: George Hart
Address Forestry Science Laboratory
Logan, Utah 84321

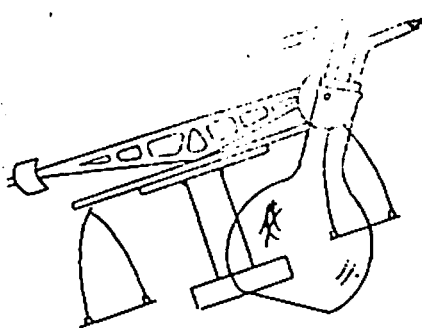
CERTIFICATE OF ANALYSIS

76-5007

Sample Water Labeled Gage Received on July 23, 1976, Zion Park Research:

Turbidity	<u>20.0</u> JTU	Fluoride as F	<u>0.32</u> mg/l
Conductivity	<u>820.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>234.0</u> mg/l
pH	<u>7.56</u>	Iron (Total) as Fe	<u>0.120</u> mg/l
Total Dissolved Solids at 180° C.	<u>535.0</u> mg/l	Iron (Filtered) as Fe	<u>0.100</u> mg/l
Alkalinity as CaCO ₃	<u>234.0</u> mg/l	Lead as Pb	<u>0.005</u> mg/l
Aluminum as Al	<u>0.070</u> mg/l	Magnesium as Mg	<u>25.4</u> mg/l
Arsenic as As	<u>0.008</u> mg/l	Manganese as Mn	<u>0.035</u> mg/l
Bicarbonate as HCO ₃	<u>202.5</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Barium as Ba	<u>0.144</u> mg/l	Nitrate as NO ₃ -N	<u>0.02</u> mg/l
Boron as B	<u>< 0.001</u> mg/l	Phosphate as PO ₄	<u>0.065</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Potassium as K	<u>3.32</u> mg/l
Calcium as Ca	<u>51.2</u> mg/l	Selenium as Se	<u>0.077</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silica as SiO ₂	<u>9.9</u> mg/l
Chloride as Cl	<u>90.0</u> mg/l	Silver as Ag	<u>< 0.001</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sulfate as SO ₄	<u>92.0</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Sodium as Na	<u>73.0</u> mg/l
Copper as Cu	<u>0.006</u> mg/l	Zinc as Zn	<u>0.007</u> mg/l


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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: June 6, 1977

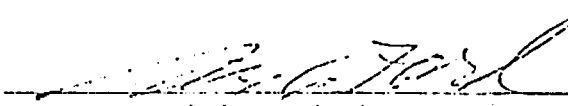
Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

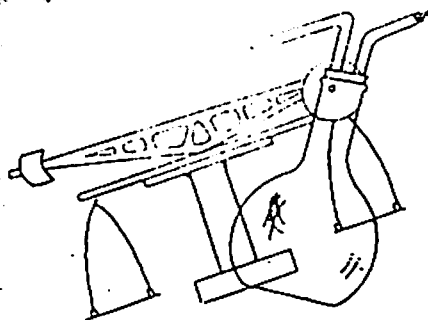
CERTIFICATE OF ANALYSIS

77-2632

Sample Water Labeled NFVR at Gage Received on May 16, 1977:

Turbidity	<u>2.00</u> JTU	Fluoride as F	<u>0.28</u> mg/l
Conductivity	<u>900.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>230.0</u> mg/l
pH	<u>7.81</u>	Iron (Total) as Fe	<u>0.086</u> mg/l
Total Dissolved Solids at 180° C.	<u>600.0</u> mg/l	Iron (Filtered) as Fe	<u>0.050</u> mg/l
Alkalinity as CaCO ₃	<u>168.0</u> mg/l	Lead as Pb	< <u>0.001</u> mg/l
Aluminum as Al	<u>0.071</u> mg/l	Magnesium as Mg	<u>42.24</u> mg/l
Arsenic as As	< <u>0.001</u> mg/l	Manganese as Mn	<u>0.034</u> mg/l
Bicarbonate as HCO ₃	<u>204.9</u> mg/l	Mercury as Hg	< <u>0.0002</u> mg/l
Barium as Ba	<u>0.091</u> mg/l	Nitrate as NO ₃ - N	<u>0.10</u> mg/l
Boron as B	<u>0.22</u> mg/l	Phosphate as PO ₄	<u>0.035</u> mg/l
Cadmium as Cd	< <u>0.001</u> mg/l	Potassium as K	<u>3.14</u> mg/l
Calcium as Ca	<u>21.6</u> mg/l	Selenium as Se	< <u>0.001</u> mg/l
Carbonate as CO ₃	< <u>0.01</u> mg/l	Silica as SiO ₂	<u>21.5</u> mg/l
Chloride as Cl	<u>130.0</u> mg/l	Silver as Ag	< <u>0.001</u> mg/l
Chromium as Cr (Hex)	< <u>0.001</u> mg/l	Sulfate as SO ₄	<u>82.0</u> mg/l
Cyanide as Cn	< <u>0.01</u> mg/l	Sodium as Na	<u>122.50</u> mg/l
Copper as Cu	<u>0.007</u> mg/l	Zinc as Zn	<u>0.042</u> mg/l


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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: June 6, 1977

Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

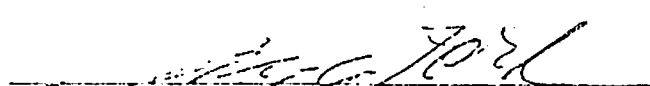
CERTIFICATE OF ANALYSIS

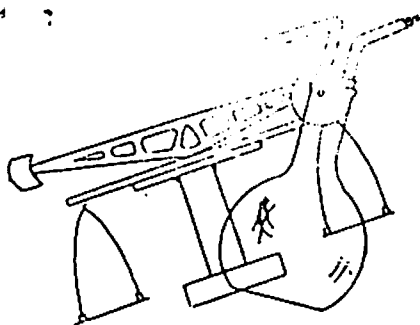
77-2633

Sample Water labeled East Fork Virgin River at Confluence w/VR Dated

May 13, 1977 Received on May 16, 1977:

Turbidity	<u>2.50</u> JTU	Fluoride as F	<u>0.35</u> mg/l
Conductivity	<u>600.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>220.0</u> mg/l
pH	<u>7.73</u>	Iron (Total) as Fe	<u>0.079</u> mg/l
Total Dissolved Solids at 180° C.	<u>400.0</u> mg/l	Iron (Filtered) as Fe	<u>0.050</u> mg/l
Alkalinity as CaCO ₃	<u>150.0</u> mg/l	Lead as Pb	< <u>0.001</u> mg/l
Aluminum as Al	<u>0.025</u> mg/l	Magnesium as Mg	<u>36.0</u> mg/l
Arsenic as As	< <u>0.001</u> mg/l	Manganese as Mn	<u>0.009</u> mg/l
Bicarbonate as HCO ₃	<u>183.0</u> mg/l	Mercury as Hg	< <u>0.0002</u> mg/l
Barium as Ba	<u>0.038</u> mg/l	Nitrate as NO ₃ -N	<u>0.70</u> mg/l
Boron as B	<u>0.14</u> mg/l	Phosphate as PO ₄	<u>0.045</u> mg/l
Cadmium as Cd	< <u>0.001</u> mg/l	Potassium as K	<u>2.97</u> mg/l
Calcium as Ca	<u>28.0</u> mg/l	Selenium as Se	< <u>0.001</u> mg/l
Carbonate as CO ₃	< <u>0.01</u> mg/l	Silica as SiO ₂	<u>22.0</u> mg/l
Chloride as Cl	<u>24.0</u> mg/l	Silver as Ag	< <u>0.001</u> mg/l
Chromium as Cr (Hex)	< <u>0.001</u> mg/l	Sulfate as SO ₄	<u>97.0</u> mg/l
Cyanide as Cn	< <u>0.01</u> mg/l	Sodium as Na	<u>30.30</u> mg/l
Copper as Cu	<u>0.003</u> mg/l	Zinc as Zn	<u>0.020</u> mg/l


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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

39

Date: June 6, 1977

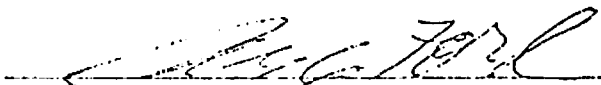
Name Utah State University
Forest Department
Address ATTN: Mr. George Hart
860 North 12th East
Logan, UT 84321

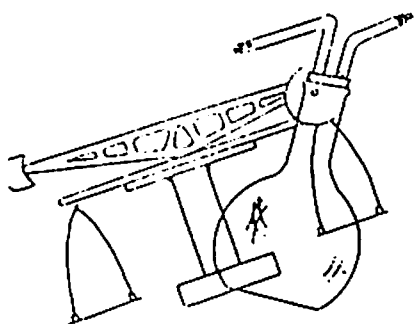
CERTIFICATE OF ANALYSIS

77-2634

Sample Water Labeled LaVerkin Creek at Hurricane Received on May 16, 1977:

Turbidity	<u>3.00</u> JTU	Fluoride as F	<u>0.40</u> mg/l
Conductivity	<u>1,670.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>486.0</u> mg/l
pH	<u>7.62</u>	Iron (Total) as Fe	<u>0.096</u> mg/l
Total Dissolved Solids at 180° C.	<u>1,105.0</u> mg/l	Iron (Filtered) as Fe	<u>0.044</u> mg/l
Alkalinity as CaCO ₃	<u>180.0</u> mg/l	Lead as Pb	<u>< 0.001</u> mg/l
Aluminum as Al	<u>0.043</u> mg/l	Magnesium as Mg	<u>64.8</u> mg/l
Arsenic as As	<u>< 0.001</u> mg/l	Manganese as Mn	<u>0.027</u> mg/l
Bicarbonate as HCO ₃	<u>219.6</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Barium as Ba	<u>0.048</u> mg/l	Nitrate as NO ₃ -N	<u>0.36</u> mg/l
Boron as B	<u>0.22</u> mg/l	Phosphate as PO ₄	<u>0.045</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Potassium as K	<u>2.93</u> mg/l
Calcium as Ca	<u>86.4</u> mg/l	Selenium as Se	<u>< 0.001</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silica as SiO ₂	<u>26.0</u> mg/l
Chloride as Cl	<u>16.0</u> mg/l	Silver as Ag	<u>0.005</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sulfate as SO ₄	<u>580.0</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Sodium as Na	<u>143.0</u> mg/l
Copper as Cu	<u>0.005</u> mg/l	Zinc as Zn	<u>0.025</u> mg/l


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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485-5761

Date: August 23, 1977

Name Utah State University
Department of Forestry
UMC 52
Address ATTN: Mr. George Hart
Logan, UT 84321

CERTIFICATE OF ANALYSIS
77-4237

Sample Water Labeled East Fork Virgin River at North Fork Conf.; Received on
August 5, 1977:

Turbidity	<u>1.6</u> JTU	Fluoride as F	<u>0.17</u> mg/l
Conductivity	<u>490.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>230.0</u> mg/l
pH	<u>8.10</u>	Iron (Total) as Fe	<u>0.125</u> mg/l
Total Dissolved Solids		Iron (Filtered) as Fe	<u>0.100</u> mg/l
at 180°C.	<u>316.0</u> mg/l	Lead as Pb	<u>< 0.001</u> mg/l
Alkalinity as CaCO ₃	<u>148.0</u> mg/l	Magnesium as Mg	<u>22.08</u> mg/l
Aluminum as Al	<u>0.113</u> mg/l	Manganese as Mn	<u>0.007</u> mg/l
Arsenic as As	<u>< 0.001</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Bicarbonate as HCO ₃	<u>180.6</u> mg/l	Nitrate as NO ₃ -N	<u>0.70</u> mg/l
Barium as Ba	<u>0.040</u> mg/l	Phosphate as PO ₄	<u>0.010</u> mg/l
Boron as B	<u>0.17</u> mg/l	Potassium as K	<u>3.57</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Selenium as Se	<u>0.003</u> mg/l
Calcium as Ca	<u>55.2</u> mg/l	Silica as SiO ₂	<u>8.0</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silver as Ag	<u>< 0.001</u> mg/l
Chloride as Cl	<u>24.0</u> mg/l	Sulfate as SO ₄	<u>98.0</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sodium as Na	<u>24.38</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Zinc as Zn	<u>0.008</u> mg/l
Copper as Cu	<u>0.002</u> mg/l		

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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
SALT LAKE CITY, UTAH 84115
PHONE 485 5761

Date: August 23, 1977

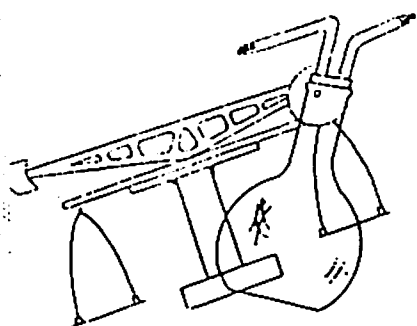
Name Utah State University
Department of Forestry
Address UMC 52
ATTN: Mr. George Hart
Logan, UT 84321

CERTIFICATE OF ANALYSIS
77-4238

Sample Water Labeled Laverkin Creek at Lees Pass Trail Received on
August 5, 1977:

urbidity	<u>1.5</u> JTU	Fluoride as F	<u>0.20</u> mg/l
Conductivity	<u>677.0</u> umhos/cm	Total Hardness as CaCO ₃	<u>330.0</u> mg/l
pH	<u>7.97</u>	Iron (Total) as Fe	<u>0.069</u> mg/l
Total Dissolved Solids at 180° C.	<u>432.0</u> mg/l	Iron (Filtered) as Fe	<u>0.040</u> mg/l
Alkalinity as CaCO ₃	<u>148.0</u> mg/l	Lead as Pb	<u>< 0.001</u> mg/l
Aluminum as Al	<u>0.063</u> mg/l	Magnesium as Mg	<u>2.3293</u> mg/l
Arsenic as As	<u>< 0.001</u> mg/l	Manganese as Mn	<u>0.004</u> mg/l
Bicarbonate as HCO ₃	<u>180.6</u> mg/l	Mercury as Hg	<u>< 0.0002</u> mg/l
Barium as Ba	<u>0.063</u> mg/l	Nitrate as NO ₃ -N	<u>0.010</u> mg/l
Boron as B	<u>0.15</u> mg/l	Phosphate as PO ₄	<u>0.010</u> mg/l
Cadmium as Cd	<u>< 0.001</u> mg/l	Potassium as K	<u>2.653</u> mg/l
Calcium as Ca	<u>84.8</u> mg/l	Selenium as Se	<u>< 0.001</u> mg/l
Carbonate as CO ₃	<u>< 0.01</u> mg/l	Silica as SiO ₂	<u>7.0</u> mg/l
Chloride as Cl	<u>8.0</u> mg/l	Silver as Ag	<u>0.014</u> mg/l
Chromium as Cr (Hex)	<u>< 0.001</u> mg/l	Sulfate as SO ₄	<u>202.0</u> mg/l
Cyanide as Cn	<u>< 0.01</u> mg/l	Sodium as Na	<u>17.10</u> mg/l
Copper as Cu	<u>0.002</u> mg/l	Zinc as Zn	<u>0.006</u> mg/l

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Bacteriological and Chemical Analysis

40 WEST LOUISE AVENUE
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PHONE 485 5761

Date: September 26, 1977

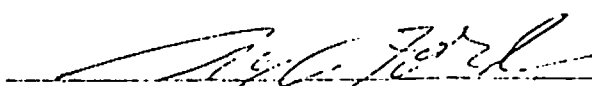
Name Utah State University
Department of Forestry
Address ATTN: Mr. George Hart
UMC 52
Logan, UT 84321

CERTIFICATE OF ANALYSIS

77-5017

Sample Water Labeled "La Verkin Creek at Lee Pass Trail" Dated September 4,
1977; Received on September 6, 1977:

Turbidity	2.0	JTU	Fluoride as F	0.15	mg/l
Conductivity	655.0	umhos/cm	Total Hardness as CaCO ₃	336.0	mg/l
pH	7.80		Iron (Total) as Fe	0.133	mg/l
Total Dissolved Solids at 180° C.	422.0	mg/l	Iron (Filtered) as Fe	0.100	mg/l
Alkalinity as CaCO ₃	152.0	mg/l	Lead as Pb	< 0.001	mg/l
Aluminum as Al	0.149	mg/l	Magnesium as Mg	32.16	mg/l
Arsenic as As	< 0.001	mg/l	Manganese as Mn	0.007	mg/l
Bicarbonate as HCO ₃	185.4	mg/l	Mercury as Hg	< 0.0002	mg/l
Barium as Ba	0.184	mg/l	Nitrate as NO ₃ -N	< 0.01	mg/l
Boron as B	0.04	mg/l	Phosphate as PO ₄	0.01	mg/l
Cadmium as Cd	< 0.001	mg/l	Potassium as K	3.70	mg/l
Calcium as Ca	80.8	mg/l	Selenium as Se	< 0.001	mg/l
Carbonate as CO ₃	< 0.01	mg/l	Silica as SiO ₂	8.0	mg/l
Chloride as Cl	10.0	mg/l	Silver as Ag	< 0.001	mg/l
Chromium as Cr (Hex)	< 0.001	mg/l	Sulfate as SO ₄	194.0	mg/l
Cyanide as Cn	< 0.01	mg/l	Sodium as Na	11.93	mg/l
Copper as Cu	0.004	mg/l	Zinc as Zn	0.033	mg/l


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