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ABSTRACT

The effects of various land uses on water quality in Summit Creek were evaluated during the period beginning March 13, 1971, and ending October 27, 1971. Potential sources of pollution investigated were: (1) septic tank use, (2) feedlot runoff, (3) urban runoff, (4) rural runoff.

Samples were collected from five sampling stations on 16 separate days during the sampling period. Analyses were performed to determine the following constituents: ammonia, nitrite, nitrate, total phosphorus, orthophosphate, coliform bacteria, chloride, suspended solids, volatile suspended solids, total carbon, organic carbon, temperature, and pH.

Agricultural activities, including livestock feedlot operations, were identified as the major source of pollutant inputs to Summit Creek.

No significant pollutant inputs could be attributed to septic tank use, urban runoff, or rural runoff.

ACKNOWLEDGMENTS

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INTRODUCTION

Nature of the problem

Summit Creek is a small mountain stream which originates in Smithfield Canyon, east of Smithfield, Utah, flows through the City of Smithfield, and continues west and flows into the Bear River. The average stream flow rate is approximately 38 cfs (33). The stream is basically spring fed and is of good quality in the higher canyon area; however, a reduction in quality occurs along the stream as it is exposed to sources of pollution. The higher canyon area is composed largely of limestone and is forested; the water reflects this condition as it is a hard water and has a high alkalinity.

The City of Smithfield, realizing the value of this stream from an aesthetic, recreational, and agricultural point of view, has become concerned about the water quality implications of increased land use in the area. Population growth in recent years has increased the intensity of land use for housing, recreation, and agriculture. Consequently, the potential for water pollution in Summit Creek from these sources has increased.

Potential pollutant sources along the stream include runoff from livestock feedlots located near the stream, runoff of a rural nature from crop and pasture lands in Smithfield Canyon, urban runoff from the City of Smithfield, and percolates resulting from septic tank use for sewage disposal in private homes.

Objectives

This study was initiated, at the request of Smithfield City, to provide water quality data for Summit Creek. The specific objectives of this study were as follows:

1. To determine the present quality of the water in Summit Creek through the measurement of applicable water quality parameters.
2. To identify major land uses in the Smithfield area which represent potential sources of pollution to Summit Creek.
3. To predict the impact of present and proposed future land uses on the water quality of Summit Creek.

LITERATURE REVIEW

Characteristics of feedlot runoff

Runoff from feedlots has been shown to be a high strength wastewater which is produced during and immediately after significant quantities of rainfall (17). Major water pollution constituents are oxygen demanding matter (principally organic), plant nutrients including nitrogen and phosphorus, infectious agents, and color and odor contributing substances (44). Miner et al. (23) described the quality of runoff from feedlots as being very high in organic content with concentrations of ammonia frequently greater than 10 mg/l, and containing very high bacterial populations.

Total solids concentrations of feedlot runoff were in the range of 300 times the concentration found in typical municipal sewage, while BOD values were approximately 100 times greater (44). Typical values of BOD are 25,600 mg/l for dairy cattle manure and 30,000 mg/l for swine manure (44). Miner (23) found suspended solids concentrations to range from 1,100 to 13,500 mg/l, chloride concentrations to range from 210 to 315 mg/l as Cl^-, and pH values to range from 7.7 to 8.4, depending upon variations in climatic conditions.

Significant nutrient concentrations have been measured from samples of feedlot runoff by Miner (23). Ranges of typical results from his study included values for phosphates of 15-80 mg/l as PO_4, nitrate nitrogen of 0.1-6.0 mg/l as N, and ammonia concentrations of 1.0-62 mg/l as N. Data presented by Loehr (16) indicated that significant nutrient concentrations were present in animal wastes. Beef cattle wastes were shown to contain 0.4 pounds N and 0.12 pounds P_2O_5 per 1,000 pounds. Wastes from hogs contained similarly high values of 0.5 pounds N and 0.3 pounds P_2O_5 per 1,000 pounds of animal weight.

High bacterial densities imply the possibility of disease transmission from animal to man. Although the incidence of such transmission is low, a dozen or more diseases do exist which can be transmitted in this manner. Among these are encephalitis, infectious bronchitis, gastroenteritis and salmonellosis (38).

Coliform counts from feedlot runoff samples have shown bacterial densities to be sizable. Median bacterial counts in the range of 64 million organisms/100 ml have been reported in a study by Miner (23). Note that the water quality standard for drinking water is 1/100 ml and for swimming 50/100 ml (20).

Cattle feedlot runoff is of highly variable quality. To predict the impact of a source of runoff on a given surface water, it is important to know the volume of flow as well as its strength. Factors contributing to variability in concentration and flow volume include temperature, frequency and intensity of rainfall, feedlot surface moisture content, and the extent of manure accumulation on the feedlot area (44). Warm temperatures and low rainfall intensities combine to allow the manure to solubilize and provide for maximum pollutant concentrations in the runoff (16).

It has also been shown that the quantity of runoff water is a function of the area of the lot, and that annual runoff volumes from feedlots may be two to three times those from adjacent cropland. Runoff volumes are also increased due to decreased soil infiltration rates resulting from the compaction of the soil by the animal hooves (44).

Another factor which tends to magnify the water pollution potential of feedlot runoff is its characteristic slug type flow pattern. This is because large quantities of high strength wastewater enter the stream over a very short period of time, allowing very little dilution to occur. If runoff volumes are high, an upset of the ecological balance of the stream may result producing fish kills, aesthetically unappealing conditions, and bacteriological conditions unsuitable for recreation (17).

Characteristics of rural runoff

The term "rural runoff" is defined in the context of this discussion to be runoff from agricultural lands including irrigated and nonirrigated croplands, as well as pasture land used for low intensity livestock grazing.

The most serious polluting substances generally attributed to rural and agricultural areas are eroded soil, nutrients, and pesticides (44). The relative amount of each of these substances which may be present in a given sample of runoff is highly variable and depends to a great extent on land management practices in the specific area. It has been shown by Weidner, Weibel, and Robeck (43) that improved land management practices can result in a marked decrease in the amount of pollution from a rural watershed. Other factors affecting the quality of runoff from this source include soil conditions, frequency and intensity of rainfall, and topographic features.

Agricultural drainage has been identified as a major contributor to nutrient enrichment in surface waters (18) (29). The heavy and uncontrolled use of nitrogenous and phosphate containing fertilizers has been pointed out as a possible cause of this nutrient enrichment (21).

Weidner et al. (43) found nutrient concentrations of runoff from croplands in wheat to be 6.0-9.0 mg/l of total nitrogen and 1.3-1.8 mg/l total phosphorus as PO_4. Studies conducted by Timmons and Holt (33) showed that the leaching of alfalfa by surface water runoff could contribute substantial amounts of nitrogen and phosphorus to lakes and streams.

Weidner et al. (43) has shown that runoff from agricultural cropland may contribute water pollutants other than nutrients to surface waters. Values which he obtained for mean concentrations of runoff constituents from croplands include: total solids, 500-540 μg/l; BOD, 2.9-7.2 μg/l; COD, 40-80 μg/l.

Median values of bacterial discharges in stormwater from a rural drainage in Ohio were given by Geldreich et al. (14). Total coliform counts obtained for each season include: Spring, 4,400/100 ml; Summer, 29,000/100 ml; Autumn, 18,000/100 ml; and Winter, 58,000/100 ml.

Runoff from livestock range and pasture land can be expected to yield many of the same pollutants as runoff from cattle feedlots, although concentrations are generally much lower (44). Reasons for this relatively low concentration include low intensity application of wastes by the animals as well as utilization of nutrients and inhibition of erosion by vegetation. Also, extensive natural treatment takes place as the runoff passes over the soil surface. Vegetation provides for effective screening of particulate matter, while mixing and aeration help to stimulate biological oxidation of organic materials (44).

Biggar and Corey (6) presented a detailed discussion and summary of data relating to agricultural drainage and eutrophication. The paper summarized not only their work but the work presented in 69 references.

Characteristics of urban runoff

Several studies have been done in relation to urban runoff for the purpose of determining the concentrations of pollutants present in water from this source (7) (12) (41). In many cases, high organic loadings, bacterial concentrations, and nutrient levels have been found (7) (41). As a result, urban runoff is considered to be a major contributor of pollutants to many surface waters in urban areas (41).

The high variability in quality of runoff from urban areas makes it very difficult to predict the impact of water from this source on receiving waters. Factors affecting runoff which contribute to this variability include land use and development features, frequency and intensity of rainfall, soil characteristics, extent of vegetation cover, ratios of hard surfaced lands to those covered with vegetation, and specific types of industry present (7).

A study in a residential and light commercial area in Cincinnati, Ohio, by Weibel, Anderson, and Woodward (41) showed urban runoff to be a significant source of high strength wastewater. Mean constituent concentrations obtained from this study included: chloride, 12 mg/l; suspended solids, 210 mg/l; volatile suspended solids, 53 mg/l; COD, 99 mg/l; BOD, 19 mg/l; nitrite nitrogen, 0.05 mg/l; nitrate nitrogen, 0.4 mg/l; ammonia nitrogen, 0.6 mg/l; total phosphate, 0.8 mg/l; and pH values of 7. Bacterial counts were also high and included values of 2,900/100 ml for total coliforms in greater than 90 percent of the samples.

Data obtained in a study by Bryan (7) on an urban drainage area in Durham, North Carolina, provided similarly high values for mean pollutant concentrations. Concentrations given include: BOD, 14.5 mg/l; COD, 179 mg/l; total solids, 2,730 mg/l; volatile solids, 298 mg/l; chloride, 12.6 mg/l; total phosphate, .58 mg/l; and fecal coliform count, 30,000/100 ml.

However, median values for drainage samples collected from streets and parks in Stockholm, Sweden, as cited by Weibel et al. (41), gave concentrations of coliforms and total solids which were significantly lower than those cited by Bryan (7) but closer to the values which Weibel et al. obtained (40). These values included coliform counts of 4,000/100 ml, COD's of 188 mg/l; total solids of 300 mg/l; and BOD's of 17 mg/l.

From the data shown, it is clear that the quality of urban runoff can vary greatly from one area to another. However, it is generally felt that, even at its best, urban runoff contains sufficient concentrations of polluting substances to adversely affect the quality of surface waters. The significance of pollution from this source depends mainly on the size and nature of the runoff area, its hydrology, and the specific nature of the receiving water and its use (41).

Performance of septic tanks and soil percolation systems

Septic tanks have been widely used in the United States since 1894 for the treatment of sewage wastes from individual dwellings and larger buildings (2). Although presently considered obsolete for use in municipal sewage treatment, septic tanks provide a simple and effective means of waste disposal where public sewerage systems are not accessible.

A septic tank is a continuous flow sedimentation tank into which sewage is allowed to flow slowly enough to allow settling of suspended matter to form sludge at the bottom of the tank. Also, particles of low specific gravity rise to the surface to form a semi-solid scum.

These solids are then broken down by anaerobic bacteria to form liquid, gas, soluble substances, and a stable residue as end products (15).

Average removal efficiencies obtained by septic tank treatment included suspended solids reductions of 65 percent at 300 ppm, BOD reductions of 65 percent at 300 ppm, and grease reductions of 70 percent at 100 ppm (40).

Typical characteristics of septic tank effluent, as given by Popkin (25), included: COD, 90-238 mg/l; ammonia nitrogen, 14.4-35.2 mg/l; nitrite nitrogen, less than 0.01 mg/l; nitrate nitrogen, less than 0.2 mg/l; organic nitrogen, 2.9-9.3 mg/l; total suspended solids, 12-96 mg/l; and volatile suspended solids, 9-66 mg/l. Also, chloride levels average approximately 140 mg/l (40).

The success or failure of a septic tank system depends largely on the performance of the soil drainage field (2) (5) (9). As the effluent percolates through the soil system, adsorption of nutrients, bacteria, and chemical substances occurs, along with biological oxidation of organic matter to stable end products (15). Failure of this soil system can result in poor quality effluents with a resulting degradation of groundwater as well as surface water.

The main reasons for failure of percolation systems according to McGauhey and Winneberger (20) include: insufficient percolative capacity of the soil; prevention of water percolation due to impermeable strata; reduced percolative capacity due to the reaction of clay colloids with chemicals present in the sewage; and the presence of a shallow groundwater table which causes the liquid to remain suspended in the soil due to surface tension and capillary phenomena, thus preventing drainage.

To help prevent the failure of leaching fields, it is generally required by state codes that suitable soil exploration to a depth of approximately 10 feet be conducted, including adequate percolation tests, in order to provide complete information on the subsoil conditions (37). However, Bendixen (4) points out that this is probably not necessary in areas with homogeneous soil conditions, particularly in the faster percolation ranges characteristic of soils containing large amounts of sand and gravel.

Soils found to have excessively high percolation rates, that is, showing a drop of 1 inch in less than 4 minutes, are said to be unsuitable for leaching fields. This is because such soils do not provide adequate resistance to hydraulic flow, and thus, allow insufficient detention time for bacterial decomposition of organic matter. Soils found to have percolation rates less than 1 inch in 60 minutes are not capable of accepting the necessary hydraulic loadings, and are thus unsuitable for any type of drainage field (9).

The loading of a soil system with sewage can cause physical, chemical, and biological clogging problems which do not occur under the application of pure water as in the percolation tests. For example, Loehr (16) has shown that failure of leaching systems due to soil clogging is directly related to the total suspended solids and BOD of the liquid applied. It has also been reported that percolation rates in clay soils may change over an extended loading period due to swelling (4). Thus, percolation data cannot be taken literally but must be carefully interpreted in order to provide adequate design criteria for leaching facilities for septic tanks.

MATERIALS AND METHODS

Selection of sampling stations

Prior to the selection of sampling stations, a preliminary survey of the watershed area was conducted. The purpose of this survey was to become familiar with the area in order to facilitate the proper selection of sampling stations. The survey included consulting United States Geological Survey maps and aerial photographs of the area which provided information as to topographic features and general land use practices. A physical inspection from the National Forest boundary to a point approximately one mile west of Smithfield gave information as to the specific characteristics of the stream and the area immediately adjacent to the stream. Also, the watershed area was viewed by air from the Utah State University airplane in order to take photographs and to identify potential sources of pollution. However, this was done after the sampling stations had been selected and collection of samples had begun.

Following the preliminary investigation, five sampling stations were selected along the stream at the locations shown in Figure 1. These locations were chosen in an attempt to isolate potential sources of pollution according to general land use classifications. In this manner, the increase in pollutant concentrations attributable to each land use classification could be measured. Ease of accessibility to aid in sample collection was also a factor in station selections.

Station 1 was chosen near the National Forest boundary. It marks the upper bound of the study area, and was chosen mainly to measure the water quality constituents present in the stream from natural background sources. However, limited use for grazing of livestock in the summer, as well as recreational uses such as hunting, camping, and fishing probably contributed to the concentrations of the various constituents measured at this station.

Station 2 was chosen at a point approximately 3 miles below Station 1. The major sources of pollution located in the watershed affecting this station were two small livestock feedlots. Also, the influence of runoff from agricultural sources, including pastures used for the grazing of cattle and irrigated croplands, was included in the measurements at Station 2.

Station 3 was chosen near the eastern edge of the City of Smithfield. The watershed affecting this station was basically rural and was composed of a mixture of scattered private dwellings and agricultural lands. Limited grazing of livestock was also present in this area.

Station 4 was chosen on the west side of Smithfield at a point beyond the center of town. The main function of this station was to measure the effects of percolates resulting from septic tank use in Smithfield. The city has no municipal sewerage facilities, and as a result, all private dwellings in the area have individual septic tanks with subsurface soil drainage fields. Urban runoff from the city streets in Smithfield also contributed to the concentrations measured at Station 4.

Station 5 was selected to measure the concentrations attributable to livestock operations west of Smithfield. It is located approximately 1 mile beyond Station 4. The effects of septic tank use in private homes scattered throughout this area should also be measured at Station 5.

Sample collection

Water samples were collected at each sampling station at approximately two-week intervals beginning March 11, 1971, with the final samples collected on October 27, 1971. Approximately one liter of sample was collected at each station on each sampling day. The samples collected between March 11, 1971, and June 5, 1971, were frozen initially and stored until June 14, 1971. At this time, the samples were thawed and the analyses performed. Samples collected from June 22, 1971, through the end of the sampling period were not frozen, but were stored at approximately 4°C for a short period until the analyses were completed.

Temperature measurements and bacterial analyses were performed in the field at the time of sampling. All other analyses were done in the laboratory.

During the course of the sampling period, information was obtained through personal communication with various land owners in the area (10) (14). This information was basically related to land use practices in Smithfield Canyon.

Analytical techniques

All of the water samples from Summit Creek that were analyzed in the laboratory were done according to analytical techniques accepted as standard procedures in

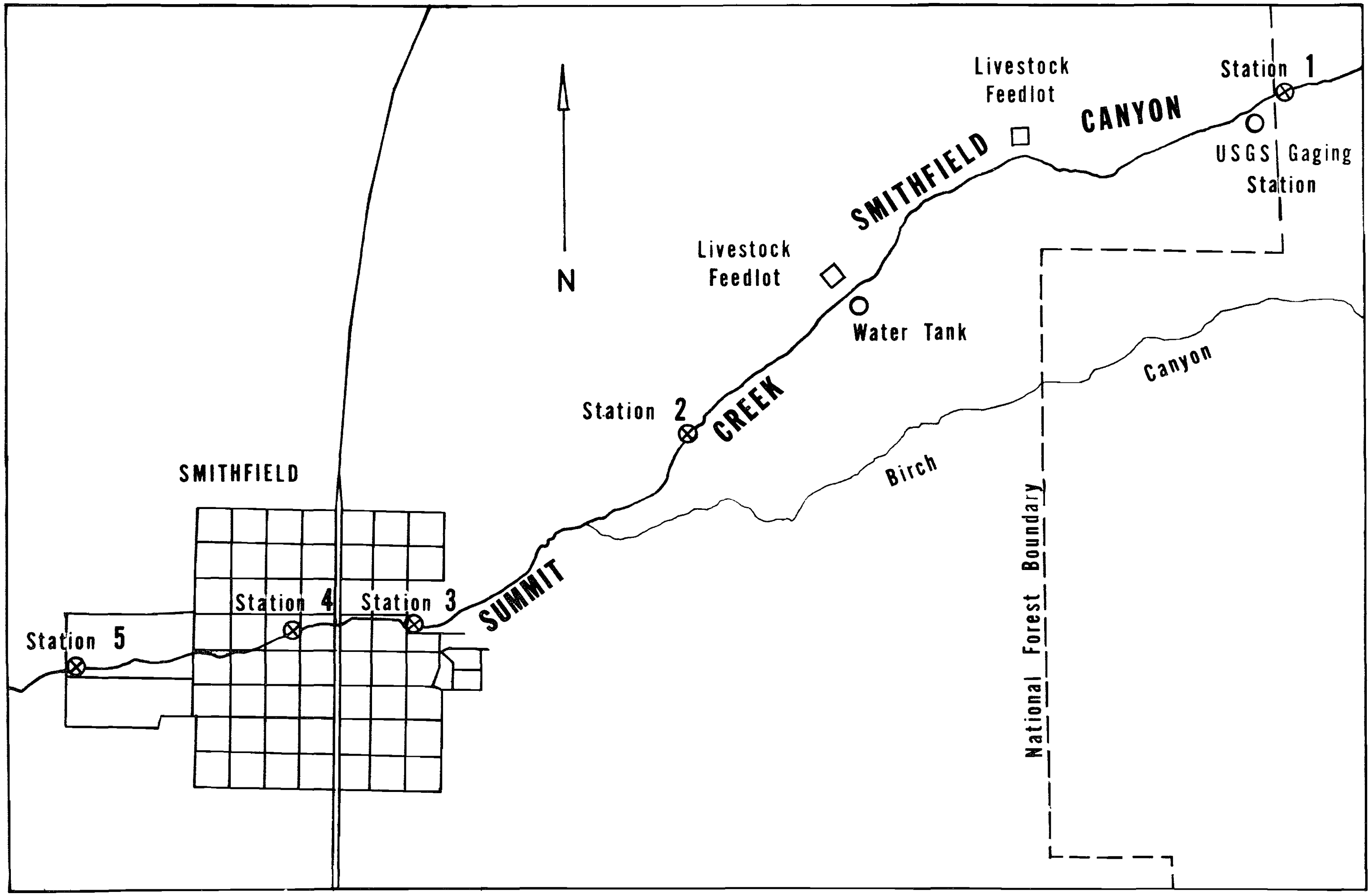

Figure 1. Map of the Smithfield area.

the water chemistry laboratory at the Utah Water Research Laboratory (see 1). Reasonable care was exercised and the recommended checks of the methods were performed to insure the reliability of the values obtained. All analyses were run on single aliquots of each sample with the exception being the bacterial determinations. (See Appendix A for all analytical results.)

Total carbon and organic carbon concentrations were determined using the Beckman Model 915 Carbon Analyzer. The procedures followed were as outlined in the Beckman Model 915 instruction manual (3).

Chloride concentrations of the water samples were determined according to procedures outlined in Standard Methods (1).

A Beckman Zeromatic II pH meter with a glass electrode was used to determine the pH values of the samples.

The total phosphorus analyses were performed according to the Federal Water Pollution Control Administration persulfate digestion procedure (13, also see 1).

Nitrate nitrogen, nitrite nitrogen, suspended solid, volatile suspended solids, and orthophosphate determinations were performed according to methods outlined by Strickland and Parsons (32, also see 1).

Procedures developed by Solorzano (31, also see 1) were used to determine ammonia nitrogen concentrations.

Bacterial analyses were performed in the field using Millipore Field Monitors according to the procedures outlined in the instruction booklet (22). Briefly, the procedure involves the filtering of a given volume of sample through the filter, transfer of the filter to an incubator for a period of 18-24 hours, and then counting the bacterial colonies. The results were recorded as counts or number of coliforms per 100 ml of sample. The volume of sample filtered was varied according to the bacterial concentrations in order to obtain countable numbers of colonies on the filters. These values were then converted to counts/100 ml as shown in Appendix A.

Statistical analysis

Statistical analyses of the data were performed according to Dixon and Massey (11) using the generalized t-test for the comparison of means from two populations of different sizes. The 95 percent level of significance was selected for all tests performed.

The mean values obtained over the sampling period at each station were compared to show any significant changes which may have occurred from station to station as the flow moved downstream. These comparisons were made for each constituent that was measured.

Coliform data were also compared from station to station for each individual sampling date to provide a more detailed analysis of the variations in concentrations throughout the sampling period. This type of analysis was possible because two coliform samples were collected at each station, allowing the comparisons of individual means. All other analyses were run on single samples; therefore, individual values for each sampling date could be compared statistically.

RESULTS AND DISCUSSION

Results of water sample analyses

The following pages contain a summary of results obtained from the analysis of water samples collected from Summit Creek from March 13, 1971, through October 27, 1971. Samples were collected on 16 separate days during the sampling period. However, the stream was diverted for irrigation use at a point just below Station 4 from mid-July until the end of September, leaving Station 5 dry. As a result, only 10 samples were collected at this station. Samples were not collected at Station 1 on March 25, 1971, because of poor road conditions.

When comparing average values from station to station, consideration was given to the fact that samples were collected from Station 5 only during the spring and early summer. Due to extreme variations in pollutant concentrations during this period, the average values at Station 5 are biased in many cases, and cannot be compared directly with values for the other stations which were obtained by averaging the results from samples collected throughout the entire sampling period. As a result, equivalent values for the same time period were compared in certain cases where it was felt that additional information could be obtained from such an analysis.

Results of the sample analyses are generally expressed as milligrams per liter (mg/l), or as micrograms per liter (μg/l) for the lower concentrations, as in the nutrient analyses. Mass flow relationships, obtained by combining constituent concentrations with flow volume, are given in pounds per day (lb/day), and coliform counts are expressed as number of coliforms per hundred milliliters of sample (coliforms/100 ml). These results are plotted for each constituent in Figures 2 through 18 to show variations in concentration with time for each sampling station as well as variations from station to station.

Coliform bacteria. The results of the bacterial analyses showed the total coliform counts to be highly variable, with values ranging from < 1/100 ml to 6,080/100 ml. A plot showing these variations over the course of the study period is given in Figure 2.

Statistical analysis of the average coliform counts from station to station showed the occurrence of a significant increase between Stations 1 and 2. This would indicate that a significant influence was being exerted on the bacterial quality of the stream by agricultural activities, including livestock operations, in this drainage area.

Further statistical analyses failed to show any significant difference between the average counts for Stations 2 through 4. However, as shown in Figure 2, the average counts tend to decrease from Station 2 to 3, and then gradually increase again at Stations 4 and 5.

The decrease in coliform concentration from Station 2 to Station 3 can be explained in part by the contribution of a small stream which flows from Birch Canyon and enters Summit Creek between these stations. Laboratory analyses on selected water samples from this stream showed coliform concentrations to be well below those in Summit Creek. As a result, this stream is considered to be a source of dilution water to Summit Creek which is responsible for the decrease in coliform concentration between Stations 2 and 3.

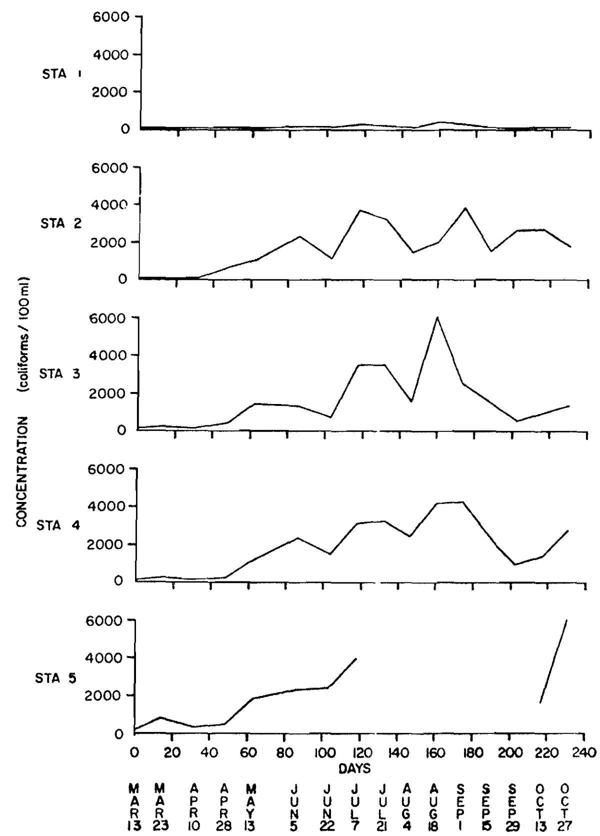

Figure 2. Variations in concentration of total coliforms with time in Summit Creek.

However, estimates based on cross sectional area and velocity measurements indicate that the flow from Birch Canyon is approximately 15 percent of the flow in Summit Creek. This quantity of flow is sizable enough to account for a significant portion of the variability that was observed in constituent concentrations from Station 2 to Station 3.

To aid in further interpretation of the coliform data, the results obtained on each sampling date were considered separately rather than as a composite over the entire sampling period. Statistical comparisons were made on each of these sets of data to determine if the coliform concentrations varied significantly from station to station. Such an analysis for each sampling date was possible only for the coliform data, because duplicate samples were collected at each sampling site only for the coliform analyses, which were run in the field, while all other analyses were run on single aliquots of each sample.

As was expected, the comparison of Station 1 to Station 2 showed a significant increase in coliforms for all 16 sampling dates, as was shown by the analysis of mean values.

Coliform counts from Station 3 to Station 4 were found to increase significantly on 10 of the 16 sampling days. A significant decrease occurred on only 1 day, with no change on the remaining 5 days. This indicates that on the majority of the sampling days, a significant influence was being exerted on the stream, between Stations 3 and 4, with respect to bacteriological quality. Probable sources of these increases include urban runoff and percolation from septic tanks in private dwellings in the City of Smithfield.

Calculations (shown in Appendix B) based on the average coliform data for the entire study show that approximately 7.5 gallons per day of sewage would have to be discharged into Summit Creek to cause the observed increase in coliform concentration. This value was obtained assuming the sewage was discharged directly into the stream. In reality, sewage would pass through a soil percolation system within which rapid die away of the coliform bacteria occurs. Thus, it is evident that no significant volumes of septic tank effluent are being discharged directly into Summit Creek. This does not eliminate the possibility that septic tank effluent percolates through the soil and eventually enters the stream. However, considering that the majority of the homes in the area have basements, the septic tanks and tile fields are buried well below the surface of Summit Creek and it is unlikely that effluent would reach the creek directly. In a porous soil it is possible that the septic tank effluent would follow the water table and enter the stream at a point below the location of the septic tank. But, after passing through many feet of soil, it is unlikely that any significant increase in coliform concentration would occur. Therefore, it appears reasonable to conclude that septic tank effluent plays a very small role in the quality of the water in Summit Creek.

An attempt was made to correlate the coliform data with precipitation data in order to more specifically identify the contribution of each runoff and percolation to the coliform populations in the stream. However, no significant relationship was found to exist. For this reason, it was concluded that both runoff and percolation could be contributing to the increase in coliform bacteria, but the relative magnitude of each contribution cannot be measured at this time.

The comparison of values from Station 4 to Station 5 showed a significant increase in coliforms for 7 of the 10 sampling days, equal values for 3 of the 10 days, and no decreasing values. Average values of coliform concentrations for the ten sampling dates on which samples were collected from both Station 4 and Station 5 were 1,303 coliforms/100 ml and 2,010 coliforms/100 ml respectively. This increase represents a statistically significant increase in concentration between Stations 4 and 5. These increases are attributed to the leaching of animal wastes from livestock feedlots located west of town.

Solids concentrations. Solids determinations included measurements of suspended solids and volatile suspended solids. The range of values measured was from 1.0 mg/l to 352.3 mg/l for suspended solids, and from 0.5 mg/l to 39.5 mg/l for volatile suspended solids.

As shown in Figures 3 and 4, solids concentrations varied according to seasonal changes, with maximum values occurring in the spring and early summer when runoff from snowmelt was high. A similar trend is shown in Figure 5 for the mass flow of solids in lbs/day. Precipitation in the form of rain and snow was observed to increase the solids concentrations in Summit Creek during the course of the study. However, the increases due to precipitation were relatively small as compared to the solids increases attributed to runoff from snowmelt in the spring and early summer. Volatile suspended solids values were approximately 10 to 15 percent of suspended solids values in the higher ranges measured, with the percentage increasing during the late summer as overall values decreased. This indicates that the organic loadings are relatively small as compared to the overall sediment loadings from runoff in the area.

Table 1 shows the average solids concentrations obtained for each sampling station as well as the average flow of solids in lbs/day. Statistical analysis shows that no significant difference exists between these average values from station to station. However, in all three cases, the trend appears to be toward a slight increase in solids values as would normally be expected as the water moves downstream. The high average values given for Station 5 are attributed to the fact that the majority of samples

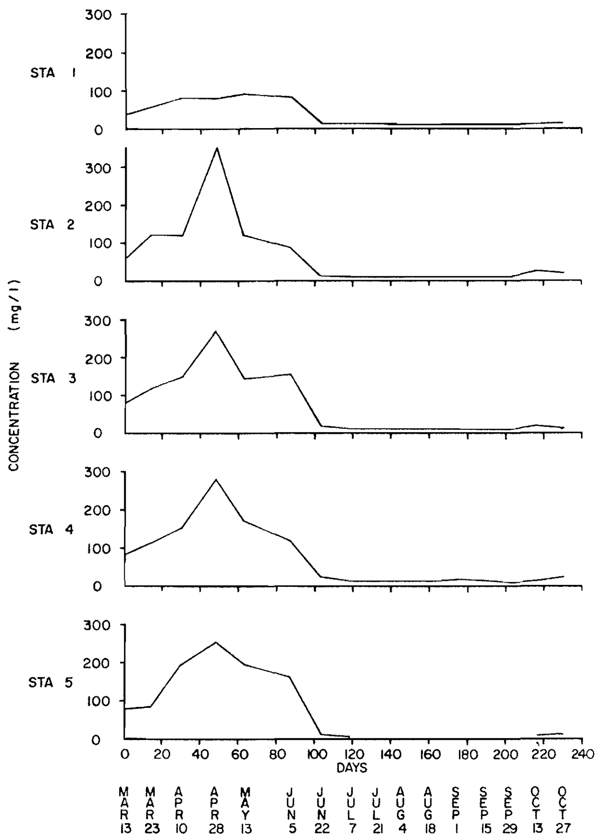

Figure 3. Variations in suspended solids concentration with time in Summit Creek.

were taken during the high runoff period. Agricultural activities were determined to contribute the majority of the solids loading to Summit Creek during the study period. An average increase of 5,261 lbs/day of suspended solids occurred between Station 1 and 2. The two animal feedlots are felt to be responsible for a significant portion of this solids increase.

The effects of the Birch Canyon stream were not evident in comparing Stations 2 and 3. The differences in solids concentration of the two streams would not be significant because of the probably similar origin oı a significant part of the suspended solids load as snowmelt runoff.

Carbon concentrations. Total carbon and total organic carbon readings ranged from 22 mg/l to 53 mg/l, and from 1 mg/l to 20 mg/l respectively. As shown in Figure 6, total carbon readings showed a gradual increase from the beginning of the sampling period to the end. However, because of the general nature of this increase for all of the sampling stations, it was of little significance for the purposes of this study. An increase in total organic carbon readings was observed for several sampling days during the spring and early summer, as shown in Figure 7. This was attributed to high runoff flow during this time of year. As was the case with total carbon, this increase generally affected all five stations.

Table 2 shows the average carbon readings obtained from each sampling station throughout the sampling period. Neither total carbon nor total organic carbon readings show any significant changes from station to station.

Forest lands above Station 1 were the major source of organic carbon to Summit Creek during the sampling period. This is because the watershed above Station 1 is relatively large and contains significant amounts of forested area. The vegetation in this area is broken down by microorganisms with the subsequent release of significant amounts of organic carbon. As a result, this carbon is available to be carried to Summit Creek by runoff waters during spring snowmelt, as well as during periods of precipitation.

Phosphorus compounds. Phosphorus analyses for this study included total phosphorus and orthophosphate determinations. An evaluation of the mass flow of total phosphorus in the stream was also made. Average results of the phosphorus determinations are given in Table 3.

The range of values measured was 0.6 μg/l to 31 μg/l as P for orthophosphate, and 18 μg/l to 320 μg/l for total phosphorus. It was found that the higher values for total phosphorus were obtained during periods of high runoff. This is attributed to adsorption of phosphorus on the

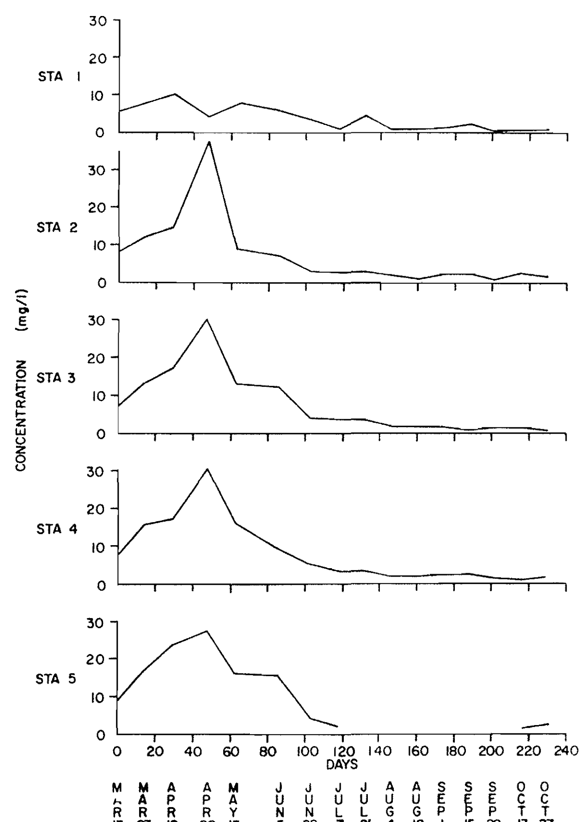

Figure 4. Variations in volatile suspended solids concentration with time in Summit Creek.

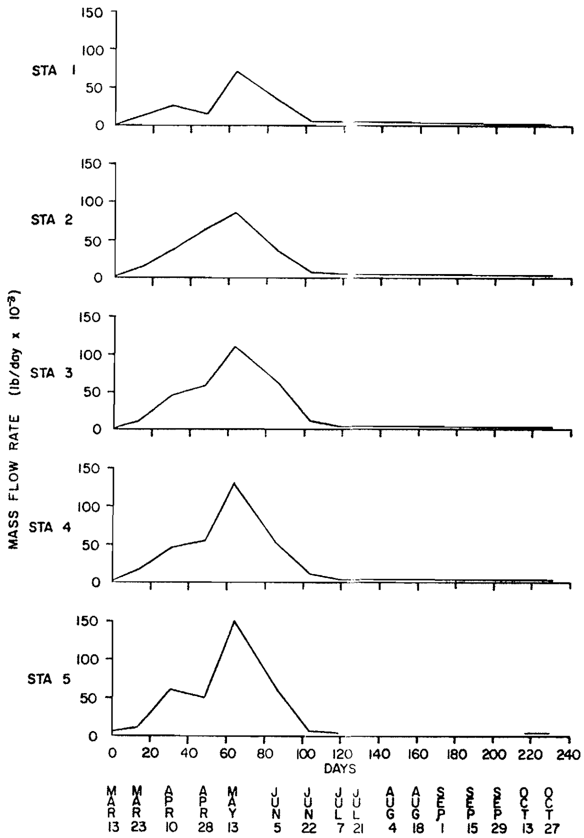

Figure 5. Variations in mass flow rate of suspended solids with time in Summit Creek.

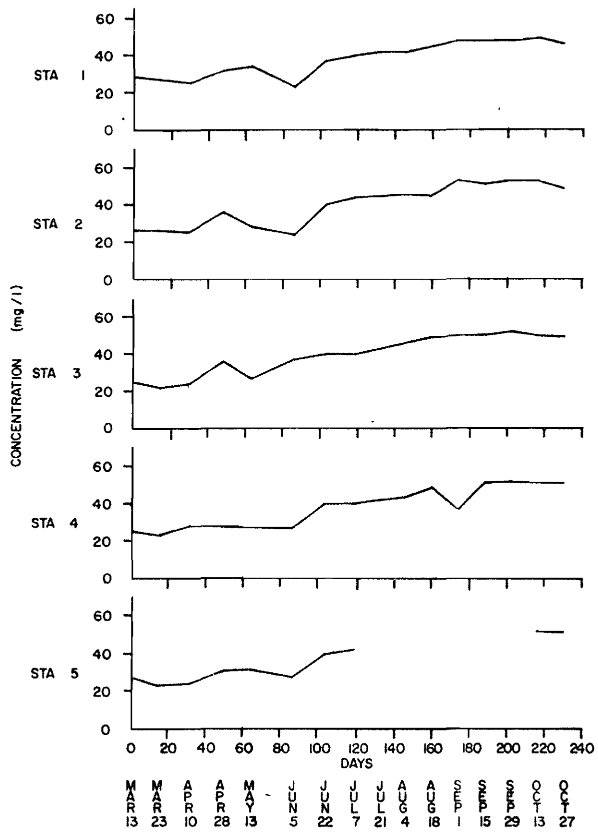

Figure 6. Variations in total carbon concentrations with time in Summit Creek.

Table 1. Average values for suspended solids concentrations, volatile suspended solids concentrations, and mass flow of suspended solids in Summit Creek.

	Sampling Stations				
Item	1	2	3	4	5
Suspended Solids (mg/l)	25.4	55.2	58.7	61.0	97.4
Volatile Suspended Solids (mg/l)	3.4	7.0	7.2	7.7	11.8
Mass Flow Suspended Solids (lb/day)	10,347.6	15,608.6	18,664.8	19,344.8	33,753.8

sediment which is carried to the stream with the runoff from snowmelt in the spring. Orthophosphate concentrations did not show a direct increase with increasing runoff. This is because the majority of phosphorus associated with high flows and resulting high solids loadings is in the form of polyphosphates and organic phosphorus. Plots of this data including a mass flow plot for total phosphorus are shown in Figures 8, 9, and 10.

Statistical analysis of the average orthophosphate concentrations shows that a significant increase occurs between Station 1 and Station 2. This increase is attributed to runoff from two livestock feedlots adjacent to the stream between these stations. Beyond Station 2, the trend is generally toward a slight decrease in average orthophosphate levels although the mass flow increases. This general decrease is attributed to the dilution effect of

Table 2. Average total carbon and total organic carbon concentrations in Summit Creek.

Item	Sampling Stations 1	2	3	4	5
Total Carbon (mg/l)	39.1	40.3	37.2	38.4	35.0
Total Organic Carbon (mg/l)	6.1	6.5	7.1	6.3	8.3

Table 3. Average values of total phosphorus and orthophosphate in Summit Creek.

Item	Sampling Stations 1	2	3	4	5
Orthophosphate (μg/l)	3.71	8.35	6.01	5.30	5.08
Total Phosphorus (μg/l)	50.6	84.2	79.7	77.2	120.8
Mass Flow Tot. P (lb/day)	15.83	24.75	25.35	22.43	39.38

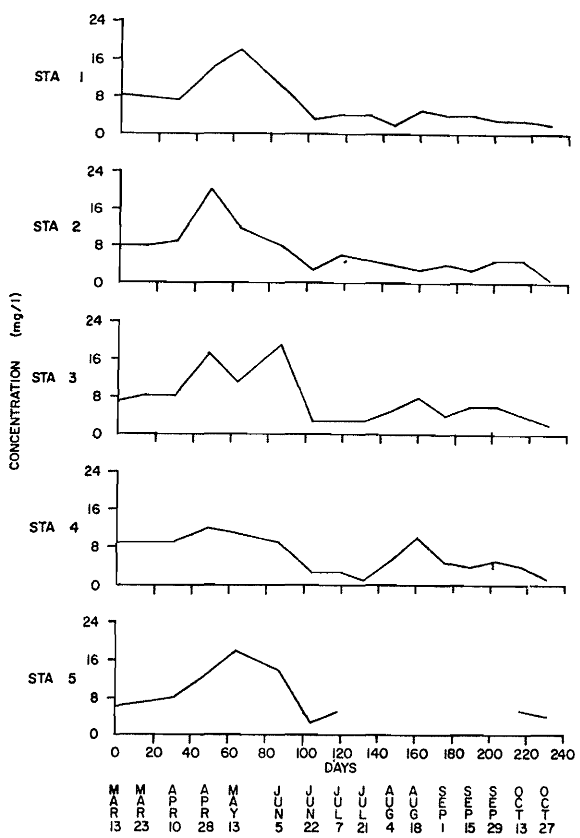

Figure 7. Variations in total organic carbon concentrations with time in Summit Creek.

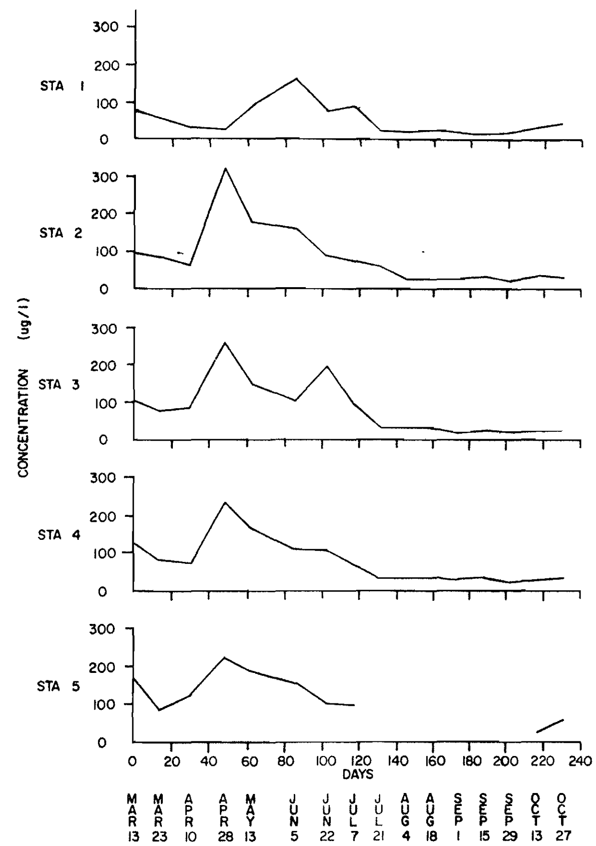

Figure 8. Variations in total phosphorus concentrations with time in Summit Creek.

the stream from Birch Canyon which enters Summit Creek, as well as the probable lack of any significant inputs of orthophosphate beyond Station 2.

Analyses of average total phosphorus levels, including mass flow calculations, show that the major increases occurred between Station 1 and Station 2. This was attributed to animal wastes from feedlots adjacent to the stream. Calculations based on mass flow data, as shown in Appendix C, yield a total phosphorus contribution for the animals in these feedlots of .032 lb/day per 100 lbs of animal weight. This value was obtained assuming that both cattle and pigs contribute equal amounts of phosphorus per pound of animal weight. Such an assump-

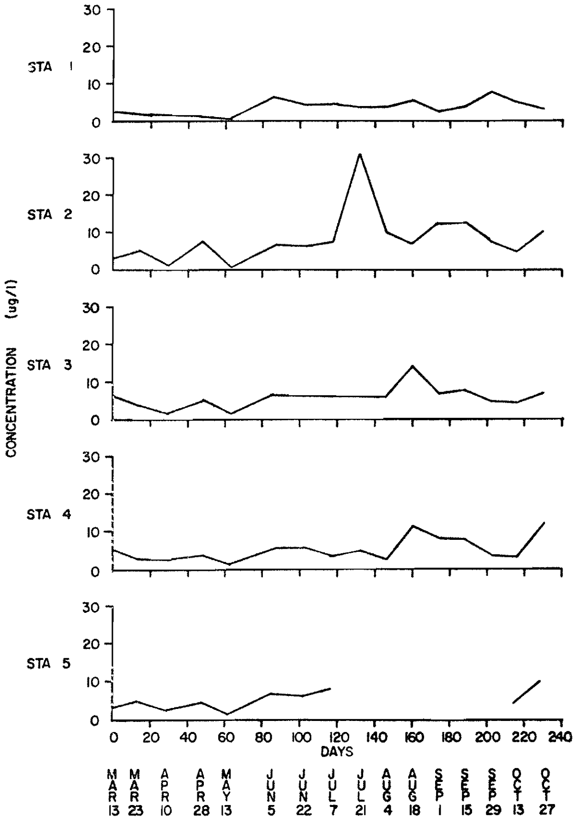

Figure 9. Variations in orthophosphate concentration with time in Summit Creek.

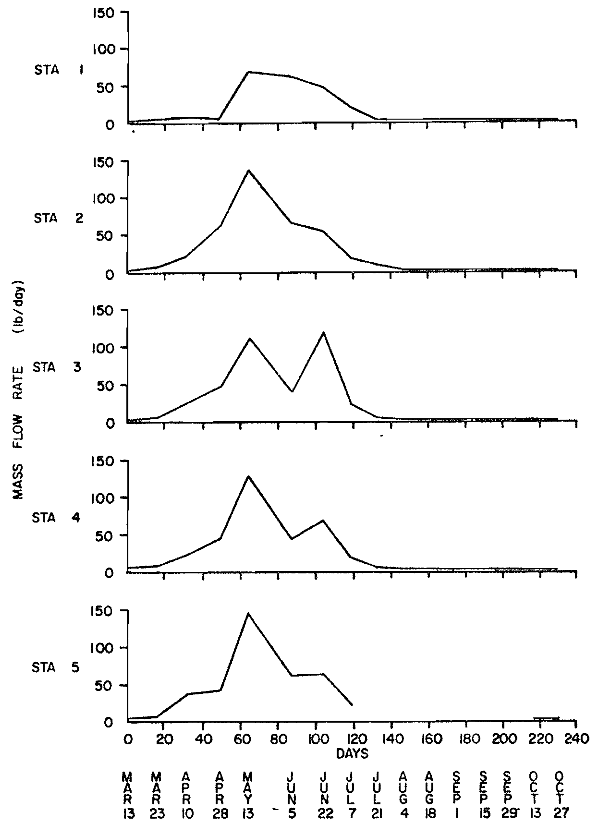

Figure 10. Variations in mass flow rate of total phosphorus with time in Summit Creek.

tion was necessary because it was impossible to separate the contributions of phosphorus with the sampling program adopted for the study. The total phosphorus values for Station 5 appear to show a significant increase. This increase is not statistically significant; however, there appears to be a trend toward increased total phosphorus values at this station. Leaching of phosphorus from livestock wastes in this area would be the most probable reason for the increase.

Nitrogen compounds. Nitrogen determinations included measurements of ammonia, nitrites, and nitrates. The results of these determinations are shown graphically in Figures 11, 12, and 13. In all cases, the concentrations obtained were below minimum values given by Reid (27) for average nitrogen levels in unpolluted fresh waters. Reid (27) reported minimum values of 1.0 mg/l for ammonia, 0.30 mg/l for nitrate, and .05 mg/l for nitrite. However, Reid's values are considerably higher than would be permitted in surface waters for prevention of eutrophication problems (e.g. 28).

Ammonia nitrogen values ranged from 4 µg/l to 129 µg/l. Values in the higher ranges occurred during the spring, indicating a possible relationship between high runoff and ammonia nitrogen concentrations. Ammonia concentrations did not increase from Station 1 to Station 2 as was the case for many of the constituents which were measured during the sampling period. This is because ammonia is oxidized or biologically assimilated at rapid rates under normal conditions; thus, it may not even be present in the feedlot runoff as it flows into the receiving water. No significant variations in ammonia concentrations were measured from Station 1 through Station 5 on Summit Creek during the study period, as is shown by the average concentrations measured (Table 4).

Nitrite nitrogen values ranged from 0.3 µg/l to 4.4 µg/l. Seasonal variations were observed with the highest concentrations occurring in the spring. Average values, as shown in Table 4, increase slightly as the flow moves downstream. However, statistical analysis shows these changes to be insignificant.

Nitrate nitrogen values were also found to vary directly with flow volume, the range being from 50 µg/l to 653 µg/l. Average values for each station, as given in Table 4, show a significant increase from Station 1 to Station 2. This increase can be attributed to runoff from agricultural lands, mainly croplands and livestock feedlots in this drainage area.

Mass flow values for nitrate nitrogen ranged from 2.56 lbs/day to 111.68 lbs/day. The higher values were observed during the spring and early summer when runoff from snowmelt was high. Seasonal variations as well as

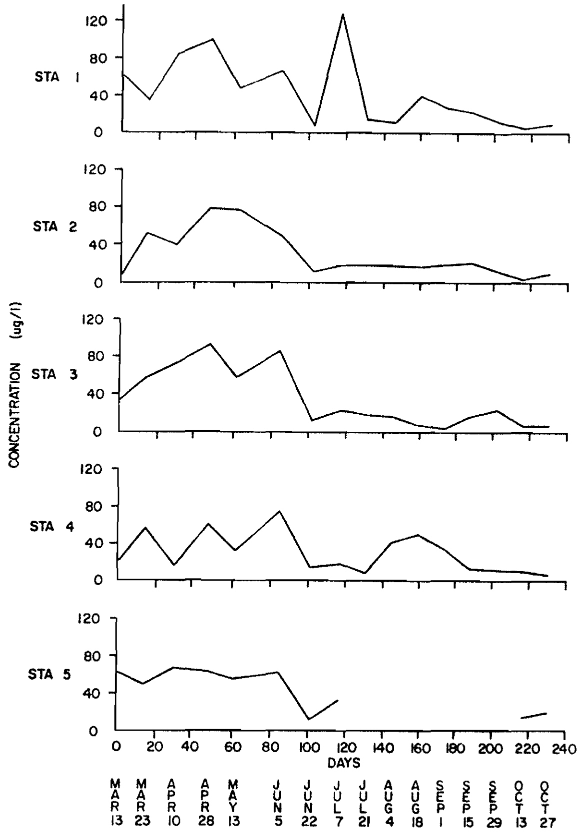

Figure 11. Variations in ammonia nitrogen concentration with time in Summit Creek.

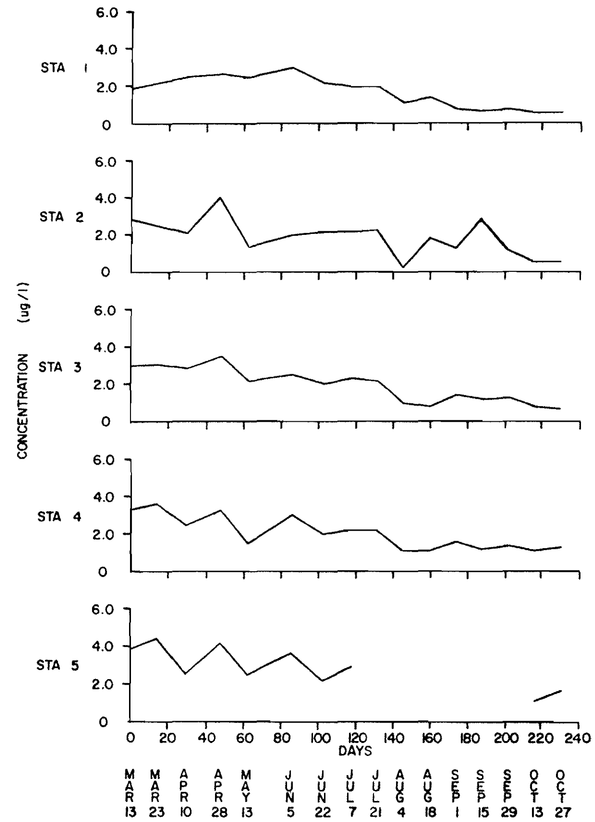

Figure 12. Variations in nitrite nitrogen concentration with time in Summit Creek.

changes from station to station are shown in Figure 14. Average mass flow values for nitrate nitrogen are given in Table 4. An increase from Station 1 to Station 2, similar to that observed for average nitrate nitrogen concentrations is apparent. This increase is attributed to the cattle feedlots located between these stations. Calculations based on mass flow data, as shown in Appendix D, yield a nitrate nitrogen contribution for the animals in these feedlots of 0.92 lbs/day per 1000 lbs of animal weight. This value compares favorably with values given by Loehr (16) of 0.4 lbs N per 1000 lbs of animal weight per day for beef cattle and 0.5 lbs N per 1000 lbs of animal weight per day for hogs.

Chloride concentrations. Chloride values obtained from the analyses ranged from 1.3 mg/l to 3.8 mg/l. Concentrations were observed to remain relatively constant throughout the entire sampling period. No noticeable variations occurred with seasonal changes or high stream flow periods, as shown in Figure 15.

Mass flow values for chlorides were found to range from 72.0 lbs/day to 1,928.8 lbs/day. As shown in Figure 16, the higher values occurred during periods of high stream flow in the spring.

Average values of chloride concentrations and mass flow of chlorides are given in Table 5. A general increase from station to station can be observed for both of these parameters. However, statistical analysis shows that these apparent increases which occurred from station to station as the water flowed downstream were not significant. Although there were no significant increases between adjacent stations, there was a sizable overall increase from the beginning of the sampling area, near the forest boundary, to the end of the sampling area, on the west side of Smithfield. This indicates that there were probably contributions of chloride to the stream from several sources, perhaps including septic tanks, but that the intensity of these sources is not great enough at present to make them measurable, at least not at a reasonable level of significance.

To further illustrate the difficulty of measuring changes in chloride levels, calculations were made to determine the amount of septic tank effluent which would have to be discharged directly into Summit Creek to raise the chloride levels significantly. Results of these calculations showed that over 45,000 gallons of septic tank effluent, or the equivalent of the total waste discharges from approximately 115 average households, would have to enter the stream to raise the chloride concentration 1 mg/l. Calculations were made assuming a

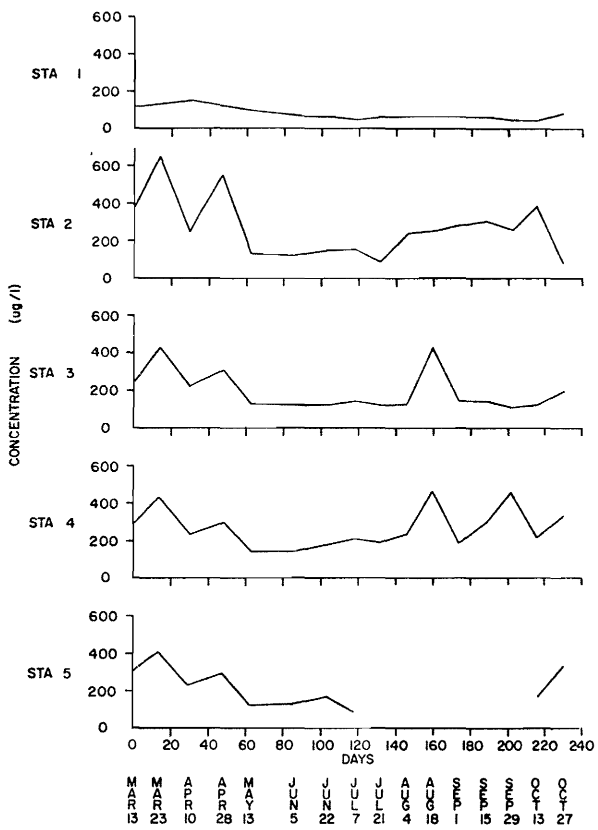

Figure 13. Variations in nitrate nitrogen concentration with time in Summit Creek.

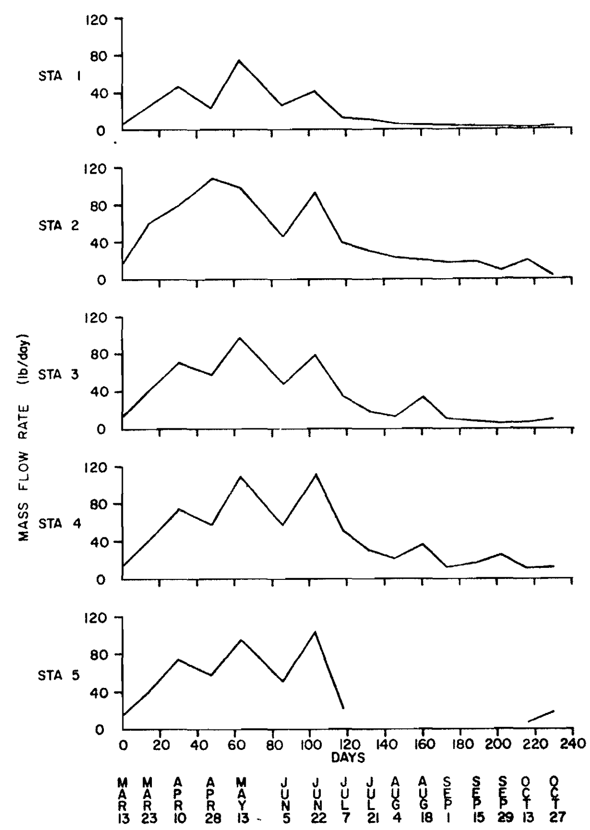

Figure 14. Variations in mass flow rate of nitrate nitrogen with time in Summit Creek.

Table 4. Average values for ammonia nitrogen, nitrite nitrogen, nitrate nitrogen and mass flow of nitrate nitrogen in Summit Creek.

Item	Sampling Stations				
	1	2	3	4	5
Ammonia-N (μg/l)	42.8	28.9	33.6	29.6	44.1
Nitrite-N (μg/l)	1.7	1.9	1.9	2.0	2.9
Nitrate-N (μg/l)	80.3	276.8	196.1	262.6	266.0
Mass Flow Nitrate-N (lb/day)	18.14	43.43	34.19	42.63	48.54

Table 5. Average chloride concentrations and mass flow of chlorides in Summit Creek.

Item	Sampling Stations				
	1	2	3	4	5
Chloride (mg/l)	2.05	2.31	2.48	2.60	2.59
Mass Flow Chloride (mg/l)	403.4	387.1	482.1	511.7	558.6

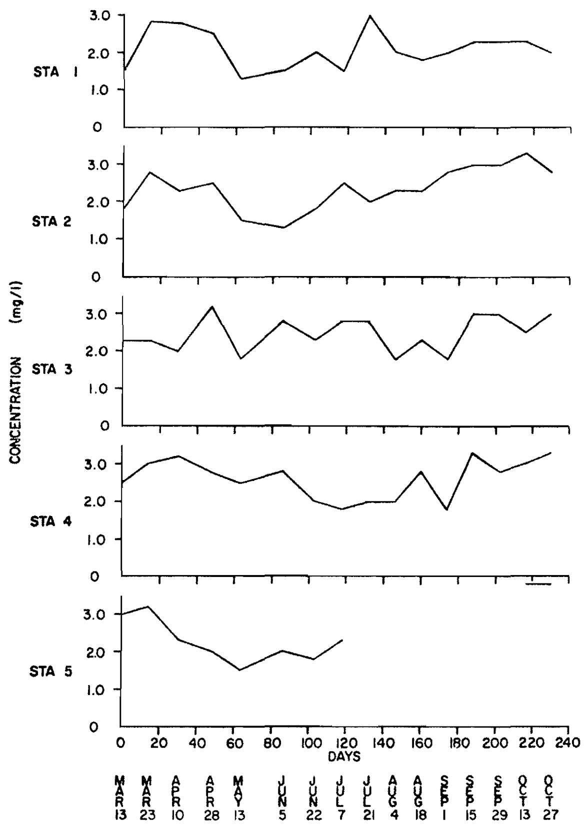

Figure 15. Variations in chloride concentration with time in Summit Creek.

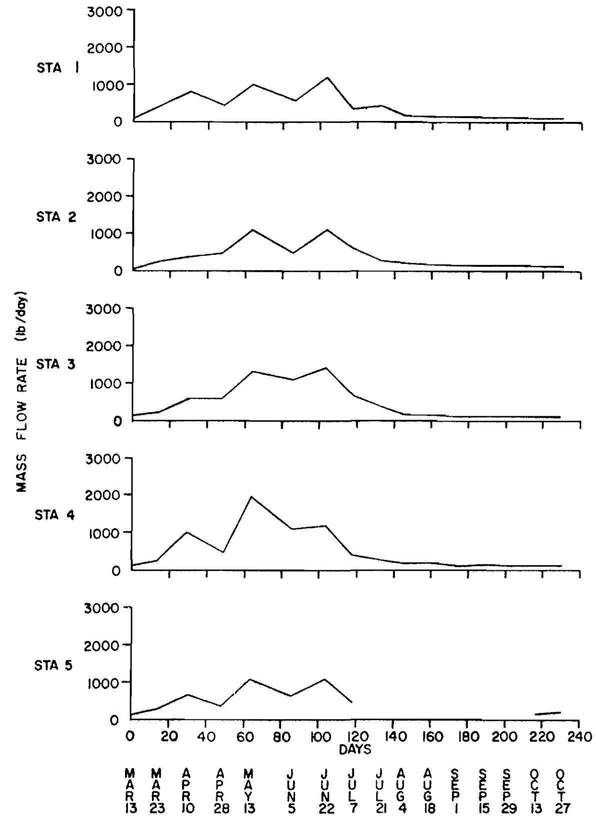

Figure 16. Variations in mass flow rate of chloride with time in Summit Creek.

flow of 10 cfs, which would provide a minimum dilution capacity, and average chloride levels from septic tank effluents were assumed to be 140 mg/l (40). Calculations are shown in Appendix E.

There are approximately 80 homes located adjacent to the stream throughout the study area. From the previous calculations, it may be seen that even if these homes were contributing large amounts of septic tank effluents to the stream on an individual basis, the overall effect would be difficult to measure.

pH values. Measurements of pH values ranged from 7.85 to 8.75. Variations throughout the sampling period were very minor, as shown in Figure 17. Average values for each station showed the stream to be slightly alkaline as would be expected in a stream of this nature (39). These values are given in Table 6. Essentially no variation in the pH value was observed from station to station.

Temperature. Temperature values were observed to increase from Station 1 through Station 5 as shown in Figure 18. This change was due mainly to the decrease in elevation as the stream flows down the canyon, and was not attributed to any major influence from land uses in the area. The average temperature values for each station are given in Table 6. The temperature value reported for Station 5 in Table 6 represents only a portion of the sampling period, and this accounts for the low value.

Stream flow data

Stream flow data for Summit Creek were obtained from the U.S. Geological Survey gaging station (36) which is located near the National Forest boundary as shown on the map in Figure 1. Flow measurements ranged from 9.5 cfs in early August to 141 cfs during the spring runoff period in May. Variations in flow throughout the sampling period are shown in Figure 19.

During the spring and early summer, stream flow rates were observed to vary directly with changes in air temperature (Table 7). This indicates that a significant portion of the flow is comprised of waters from snowmelt in the higher drainage area.

Flow rate was observed to change very little with respect to precipitation during the study period. This is because the stream is fed by a series of springs in the higher canyon area, and maintains a relatively large base flow in relation to the runoff flows that are normally added from the limited drainage area during precipitation (34).

Climatological data

Climatological data that was used in this study included measurements of precipitation and temperature (34). Data were not available for the Smithfield area

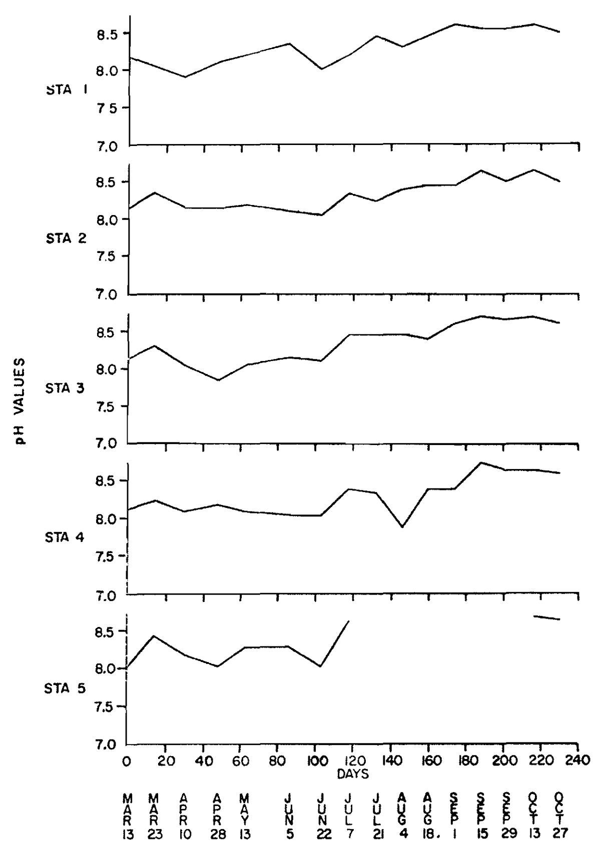

Figure 17. Variations in pH values with time in Summit Creek.

directly, so it was necessary to take the average of values measured at the Utah State University Experiment Station, which is south of Smithfield, and the Richmond station, which is north of Smithfield. In this manner, it was possible to obtain some general values of precipitation and temperature for use in this study. Table 7 contains the values obtained for precipitation and temperature in the Smithfield area during the study period.

The precipitation data were compared with the data obtained from the chemical analyses of the water samples in an attempt to find some correlation. The results of these comparisons showed that the constituent concentrations of the water in Summit Creek did not vary in a predictable manner with the occurrence of precipitation during the study period.

As mentioned previously, high flows during the spring and early summer were shown to occur concurrently with increases in temperature, indicating that the majority of the flow is comprised of runoff from snowmelt.

Soil characteristics

Information concerning the soil characteristics of lands in the Summit Creek drainage area was provided by the Cache Area Soil Survey (8). The soils of specific concern were those which are now being used, or will be used in the future, as subsurface disposal systems for septic tank effluents.

Soils in the Smithfield City area are designated in this survey as being in the Green Canyon Series. These soils are a gravelly loam, with gravel content ranging from 15 to 35 percent in the surface layer, 30 to 50 percent in the subsoil, and 50 to 80 percent in the substratum (8). The depths of these layers are 7 to 12 inches for the surface layer, 10 to 24 inches for the subsoil, and the substratum extends to a depth of more than 60 inches. Small areas of deep loamy soils are also included in this series. The permeability is moderately rapid, with percolation rates of 2.5 to 5.0 inches per hour (30). This high permeability indicates that the hydraulic capacity of the soil is sufficient to allow the application of septic tank effluent without clogging problems. Therefore, there is little probability that pollution from this source is entering Summit Creek. It is possible, however, that septic tank effluents could pass through this soil too rapidly to allow the occurrence of purification by filtering action and by the soil bacteria. If this were to occur, the groundwater supply could be adversely affected.

Soils throughout the Smithfield Canyon area contain significant quantities of gravel and exhibit the same general characteristics as the Green Canyon Series. At Station 2, near the area proposed for future housing development, the soil is of the Sterling Series. This is also a gravelly loam with moderately rapid permeability.

On the basis of this data, it appears that these soils are capable of providing adequate subsurface drainage systems for septic tank effluents. Moderately rapid percolation rates, low clay content, and the absence of impermeable strata would provide the necessary hydraulic capacity with a minimum danger of clogging. It should be

Table 6. Average values for pH and temperature in Summit Creek.

	Sampling Stations				
Item	1	2	3	4	5
pH	8.33	8.33	8.35	8.31	8.34
Temperature (°C)	8.1	9.4	10.0	10.2	9.3

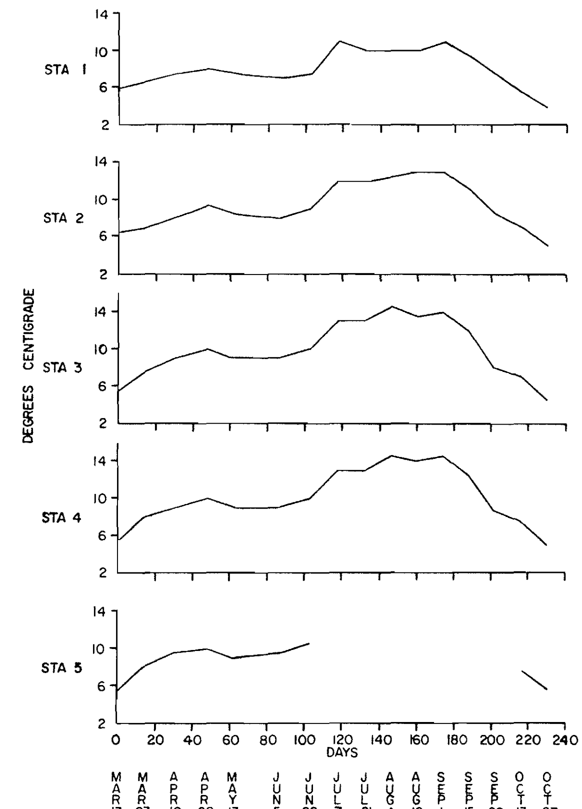

Figure 18. Variations in temperature with time in Summit Creek.

remembered, however, that proper design of these systems according to state regulations (37), is necessary to provide maximum treatment efficiencies.

General observations

From the results of the water sample analyses, it has been determined that the general quality of the water during the study period was very good with exceptions occurring during periods of high flow due to runoff from snowmelt. However, bacterial analyses show that average coliform concentrations in Summit Creek are well above the recommended mean coliform content of 50/100 ml for swimming and bathing waters (21).

Significant increases in coliform bacteria, orthophosphate, and nitrate concentrations were observed between Station 1 and Station 2 during the course of this study. These increases are attributed, for the most part, to two small livestock feedlots, one containing approximately 25 animals (10), the other approximately 10 animals (24). These feedlots are located on sloping lands immediately adjacent to the stream; thus, during periods of precipitation and snowmelt, significant quantities of animal wastes are carried into the flow resulting in increased nutrient levels and bacterial counts. The nutrient contribution to Summit Creek from these animals based on measured mass flows was calculated to be 0.092 pounds of nitrate nitrogen per 100 pounds of animal weight per day, and 0.032 pounds of total phosphorus per 100 pounds of animal weight per day. Pollution from this source produced the only mean increase in pollutant concentrations over the study period which was measurable at the 95 percent level of significance.

Gravelly soils such as those in the Smithfield area provide excellent hydraulic capacity for subsurface disposal systems, and allow the rapid passage of septic tank effluent waters through the system and into the groundwater. This rapid infiltration could create a problem in relation to the pollution of groundwater supplies by septic tank effluents which are discharged to the soil. Because many of the houses in Smithfield have basements and are thus discharging septic tank effluents well below the ground surface, the probability that the groundwater supply is being contaminated is quite high. In fact, the groundwater is more likely to be contaminated by the disposal of septic tank effluents in the soil than is Summit Creek.

On several occasions during the course of this study, results of sample analyses indicated the possibility of trends toward increasing or decreasing pollutant concentrations at certain sampling stations. However, statistical analyses of the data involved failed to show any significance concerning these trends. In many cases, this failure to show significance was attributed to the low

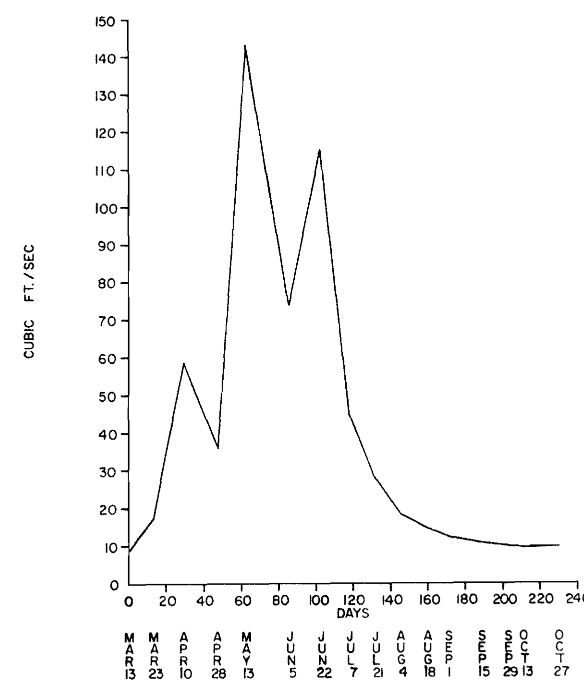

Figure 19. Variations in stream flow rate with time in Summit Creek.

intensity of land use in the area, rather than to the lack of pollution from each individual source. It was reasoned that the dilution capacity was great enough, at that time, to allow the stream to absorb these pollutant inputs without showing any significant effects.

On this basis, it is very probable that various land uses such as septic tank use, which show no significant relationship to water pollution at the present time, may become significant sources of pollutant inputs as land use intensities increase in the future.

Table 7. Stream flow rate readings for Summit Creek; precipitation and air temperature values in the Smithfield area.

Date	Flow Rate (cfs)	Temp. (°F)	Precip. (in.)
3-11-71	8.9	48-30	.07
3-25-71	17.5	53-32	.11
4-10-71	58.4	70-41	-
4-28-71	36.0	56-31	.03
5-13-71	141.0	74-46	.04
6-5-71	73.6	69-41	.17
6-22-71	115.0	94-54	-
7-7-71	45.0	85-54	-
7-21-71	28.1	88-57	.18
8-4-71	18.0	93-65	-
8-18-71	14.5	91-53	-
9-1-71	12.1		-
9-15-71	10.9	71-33	-
9-29-71	10.2	65-38	.01
10-13-71	9.5	71-32	-
10-27-71	10.0	46-32	.45

CONCLUSIONS

The following conclusions can be drawn, based on the information obtained during this study:

1. Agricultural activities, including livestock feedlot operations, have been identified as the major source of pollutant inputs to Summit Creek during the study period.

2. Average coliform counts in Summit Creek, as it flows through Smithfield, are well above the minimum values recommended for swimming and bathing waters in Utah.

3. There is no evidence to indicate that septic tank use in the Smithfield area is contributing significant pollution inputs to Summit Creek.

4. The dilution capacity of Summit Creek is great enough to allow the input of pollutants from low intensity land uses in the area without measurable effects on the quality of the water.

5. Nutrient levels in Summit Creek are very low. As a result, the stream will probably be very sensitive to future increases in nutrient levels, should any occur.

6. There is no evidence to indicate that urban runoff from Smithfield City contributed significant pollution inputs to Summit Creek during the study period.

7. Flow rates were shown to vary directly with changes in temperature during the spring and early summer. This is an indication that the flow during this period is composed largely of runoff from snowmelt in the higher drainage areas.

8. Large sediment loads, contributed principally by adjacent feedlots, are carried to the stream by high runoff flows during periods of precipitation and snowmelt.

9. Soils in the Smithfield Canyon area are generally suitable for subsurface drainage systems for the treatment of septic tank effluents. However this may lead to a contamination of the groundwater by septic tank effluents.

RECOMMENDATIONS FOR FURTHER STUDY

1. A general study of possible methods for reducing the pollutant inputs from land uses along Summit Creek should be done.

2. Detailed bacterial analyses of the water in Summit Creek should be performed to determine the potential for disease transmission by water-borne organisms.

3. Detailed studies of land use on an individual basis would provide more specific information as to the pollution potential of each land use in the area.

4. A study should be performed to determine the effects of subsurface disposal of septic tank effluents on the groundwater quality in the Smithfield area.

5. A routine sampling program should be established to determine the variation in nitrate concentration in the groundwater supply to establish the effect of the various wastes that are being discharged in the Smithfield area.

LITERATURE CITED

1. APHA. Standard methods for the examination of water and waste water. 13th ed. American Public Health Association, Inc., New York. 1971. 874 p.

2. Baumann, E. R., and H. E. Babbitt. An investigation of the performance of six small septic tanks. Bulletin series no. 409. University of Illinois Engineering Experiment Station, Urbana, Illinois. 1953. 75 p.

3. Beckman model 915 total organic carbon analyzer instructions, 81706-A. Beckman Instrument Incorporated, Fullerton, California. 1968. 32 p.

4. Bendixen, T. W. Discussion. Sewage and industrial wastes 22(9):1153-1156. 1950.

5. Bendixen, T. W., M. Berk, J. P. Sheehy and S. R. Weibel. Studies on household sewage disposal systems part II. Federal Security Agency, Public Health Service. 1950. 94 p.

6. Biggar, J. W. and R. B. Corey. Agricultural drainage and eutrophication. Proceedings of a Symposium, eutrophication: causes, consequences, correctives. National Academy of Sciences, New York. 1969. 661 p.

7. Bryan, Edward H. Quality of stormwater drainage from urban land areas in North Carolina. Water Resources Research Institute, University of North Carolina, Chapel Hill, North Carolina. 1970. 144 p.

8. Cache area soil survey–Utah. No. 103. April 1966.

9. Clark, John W. and Warren Viessman, Jr. Water supply and pollution control. International Textbook Company, Scranton, Pennsylvania. 1965. 575 p.

10. Cronquist, R. O. Resident of Smithfield. Personal interview, October 27, 1971.

11. Dixon, Wilfrid J. and Frank J. Massey, Jr. Introduction to statistical analysis. McGraw-Hill Book Company, New York. 1969. 638 p.

12. Evans, F. L., E. E. Geldreich, S. R. Weibel and G. G. Robeck. Treatment of urban stormwater runoff. Journal of the Water Pollution Control Federation 40(5):R162-R170. 1968.

13. Federal Water Pollution Control Administration. FWPCA methods for chemical analysis of water and wastes. Division of Water Quality Research, Analytical Quality Control Laboratory, Cincinnati, Ohio. 1969. 280 p.

14. Geldreich, E. E., L. C. Best, B. A. Kenner and D. J. Van Dorsel. The bacteriological aspects of stormwater pollution. Journal of the Water Pollution Control Federation 40:1861-1872. 1968.

15. Hepburn, E. A. What goes on in a septic tank. Hume News, Vol. XXVI(8). August 1950. 4 p.

16. Loehr, R. C. Animal wastes–a national problem. Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers 95:189-197. 1969.

17. Loehr, R. C. Drainage and pollution from beef cattle feedlots. Journal of the Sanitary Engineering Division, Proceedings of the American Society of Civil Engineers 96:1295-1309. 1970.

18. McCarty, P. L., Chairman of the Task Group Report. Sources of nitrogen and phosphorus in water supplies. Journal of the American Water Works Association 59:344-361. 1967.

19. McGauhey, P. H. and John H. Winneberger. Studies of the failure of septic tank percolation systems. Journal of the Water Pollution Control Federation 36:593-606. 1964.

20. McGauhey, P. H. and John H. Winneberger. Summary report on causes and prevention of failure of septic tank percolation systems. Sanitary Engineering Research Laboratory, University of California, Berkeley. May 1963. 66 p.

21. McKee, Jack Edward and Harold W. Wolf, eds. Water quality criteria. The Resources Agency of California, State Water Control Board, Sacramento. Publication No. 3-A. 1963. 548 p.

22. Millipore field monitor instructions, MRP-3. Millipore Corporation, Bedford, Massachusetts. 1967.

23. Miner, J. R., R. I. Lipper, L. R. Fina and J. W. Funk. Cattle feedlot runoff: Its nature and variation. Journal of the Water Pollution Control Federation 38:1582-1591. 1966.

24. Nilson, M. Resident of Smithfield. Personal interview, December 1, 1971.

25. Popkin, Ronald A. and T. W. Bendixen. Improved subsurface disposal. Journal of the Water Pollution Control Federation 40:1499-1514. 1968.

26. Public Health Service. Manual of septic tank practice. Government Printing Office, Washington, D.C. Publication No. 526. 1957.

27. Reid, George K. Ecology of inland waters and estuaries. Van Nostrand Reinhold Company, New York. 1961. 375 p.

28. Robeck, G. G., T. W. Bendixen, Warren A. Schwartz and Richard L. Woodward. Factors influencing the design and operation of soil systems for waste treatment. Journal of the Water Pollution Control Federation 36:971-983. 1964.

29. Sawyer, C. N. The need for nutrient control. Journal of the Water Pollution Control Federation 40:363-370. 1968.

30. Soil Survey Staff, United States Department of Agriculture. Handbook 18. Government Printing Office, Washington, D.C. August 1951. 502 p.

31. Solorzano, Lucia. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnology and Oceanography 14(5):799-801. 1969.

32. Strickland, J. D. H. and T. R. Parsons. A practical handbook of seawater analysis. Bulletin No. 167. Fisheries Research Board of Canada, Ottawa, Canada. 1968. 293 p.

33. Timmons, D. R. and R. F. Holt. Leaching of crop residues as a source of nutrients in surface runoff water. Water Resources Research 6:1367-1375. 1970.

34. U.S.D.C. Climatological data. Vol. 73. National Oceanic and Atmospheric Administration, Environmental Data Service, Asheville, North Carolina. 1971.

35. U.S.D.I. Map of Smithfield quadrangle, Utah-Cache County. Geological Survey, Denver, Colorado. 1964.

36. U.S.D.I. Stream flow data-Summit Creek gaging station no. 10102300. Geological Survey, Salt Lake City, Utah. 1971. (In press.)

37. Utah State Division of Health. Code of waste disposal regulations part V, small underground wastewater disposal systems. Adopted 1965. Salt Lake City, Utah. 16 p.

38. Wadleigh, C. H. Agricultural pollution of water resources. Soil Conservation 33:27-30. 1967.

39. Warren, Charles E. Biology and water pollution control. W. B. Saunders Company, Philadelphia, Pennsylvania. 1971. 434 p.

40. Weibel, S. R., C. P. Straub and J. R. Thoman, Jr. Studies on household sewage disposal systems. Federal Security Agency, Public Health Service. 1949. 260 p.

41. Weibel, S. R., R. J. Anderson and R. L. Woodward. Urban land runoff as a factor in stream pollution. Journal of the Water Pollution Control Federation 36:914-924. 1964.

42. Weibel, S. R., T. W. Bendixen and J. B. Coulter. Studies on household sewage disposal systems part III. Federal Security Agency, Public Health Service. 1954. 143 p.

43. Weidner, R. B., S. R. Weibel and G. G. Robeck. Rural runoff as a factor in stream pollution. Journal of the Water Pollution Control Federation 41:377-384. 1969.

44. Willrich, Ted L. and George E. Smith, eds. Agricultural practices and water quality. Iowa State University Press, Ames, Iowa. 1970. 415 p.

Appendix A

Analytical Results for Collected Samples at Each Site and Date

Table 8. Concentrations of coliform bacteria in Summit Creek (coliforms/100 ml).*

Date	Sampling Stations 1	2	3	4	5
3-11-71	0.0	120.0	165.0	165.0	217.5
3-25-71	-	155.0	205.0	265.0	822.5
4-10-71	9.0	82.5	135.0	105.0	350.0
4-28-71	40.0	730.0	430.0	280.0	570.0
5-13-71	41.0	1,136.5	1,267.5	1,200.0	1,905.0
6-5-71	194.5	2,350.0	1,260.0	2,340.0	2,315.0
6-22-71	125.0	1,180.0	720.0	1,500.0	2,410.0
7-7-71	310.0	3,700.0	3,560.0	3,100.0	4,000.0
7-21-71	213.0	3,420.0	3,560.0	3,280.0	-
8-4-71	160.0	1,550.0	1,620.0	2,450.0	-
8-18-71	435.0	2,020.0	6,080.0	4,160.0	-
9-1-71	348.0	3,900.0	2,500.0	4,325.0	-
9-15-71	125.0	1,520.0	1,775.0	2,450.0	-
9-29-71	30.0	2,650.0	575.0	975.0	-
10-13-71	125.0	2,760.0	900.0	1,350.0	1,510.0
10-27-71	181.0	1,800.0	1,340.0	2,730.0	6,000.0
Mean Value	155.7	1,817.1	1,630.8	1,917.2	2,010.0

*Values given are average values for each station.

Table 9. Suspended solids concentrations in Summit Creek (mg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	30.5	57.3	74.8	81.0	77.0
3-25-71	-	119.5	113.0	111.3	81.0
4-10-71	81.0	116.3	145.0	148.0	191.5
4-28-71	75.8	352.3	267.8	279.0	253.3
5-13-71	91.0	116.3	141.0	168.5	190.8
6-5-71	78.3	82.8	150.5	115.8	159.3
6-22-71	5.8	7.3	13.0	14.0	9.5
7-7-71	1.5	6.5	7.3	7.0	3.5
7-21-71	5.5	3.8	6.8	7.3	-
8-4-71	1.5	2.5	2.3	3.0	-
8-18-71	1.3	1.5	2.5	6.0	-
9-1-71	2.0	3.0	2.5	13.0	-
9-15-71	3.0	3.5	3.3	8.1	-
9-29-71	1.3	1.8	2.3	3.3	-
10-13-71	1.0	5.0	3.8	4.5	2.5
10-27-71	1.5	3.8	3.0	6.0	5.8
Mean Value	25.4	55.2	58.7	61.0	97.4

Table 10. Volatile suspended solids in Summit Creek (mg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	5.5	8.3	7.3	7.8	8.3
3-25-71	-	12.0	13.3	15.5	16.8
4-10-71	10.0	14.8	17.3	17.5	23.8
4-28-71	4.3	39.5	30.3	30.8	27.5
5-13-71	7.5	8.8	13.3	16.0	16.3
6-5-71	6.0	7.0	12.3	9.3	15.5
6-22-71	3.5	3.0	4.0	5.0	4.3
7-7-71	1.0	2.8	3.8	3.5	2.3
7-21-71	4.5	3.0	3.3	3.5	-
8-4-71	1.0	2.0	1.8	2.0	-
8-18-71	1.0	1.0	1.8	2.0	-
9-1-71	1.5	2.3	1.8	2.5	-
9-15-71	2.3	2.3	1.0	2.8	-
9-29-71	.5	1.0	1.8	1.8	-
10-13-71	.8	2.3	1.5	1.3	1.3
10-27-71	1.0	1.8	1.0	2.0	2.3
Mean Value	3.4	7.0	7.2	7.7	11.8

Table 11. Mass flow suspended solids in Summit Creek (lb/day).

Date	Sampling Stations 1	2	3	4	5
3-11-71	1,464.5	2,751.4	3,591.7	3,889.4	3,697.4
3-25-71	-	11,282.8	10,669.1	10.508.6	7,647.8
4-10-71	25,521.6	36,664.0	45,686.9	46,632.0	60,338.2
4-28-71	14,722.5	68,426.7	58,014.4	54,189.8	49,198.1
5-13-71	70,208.3	89,727.7	108,784.2	130,001.0	147,205.9
6-5-71	39,092.1	32,879.0	59,762.0	49,983.0	62,256.4
6-22-71	3,598.5	4,529.1	8,065.5	8,686.0	5,894.0
7-7-71	364.2	1,578.0	1,772.3	1,699.4	849.7
7-21-71	833.8	576.1	1,030.9	1,106.7	-
8-4-71	145.7	242.8	223.4	291.3	-
8-18-71	101.7	117.3	195.6	469.4	-
9-1-71	130.6	195.8	163.2	848.6	-
9-15-71	176.4	205.8	194.1	476.3	-
9-29-71	71.5	99.1	126.6	181.6	-
10-13-71	51.3	256.3	194.8	230.6	128.1
10-27-71	80.9	205.0	161.9	323.7	312.9
Mean Value	10,437.6	15,608.6	18,664.8	19,344.8	33,753.8

Table 12. Total carbon concentrations in Summit Creek (mg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	28	26	25	25	27
3-25-71	-	26	22	23	23
4-10-71	25	25	24	28	24
4-28-71	32	36	36	28	31
-13-71	34	28	27	27	32
6-5-71	23	24	37	27	28
6-22-71	37	40	40	40	40
7-7-71	40	44	40	40	42
7-21-71	42	45	43	42	-
8-4-71	42	46	46	44	-
8-18-71	45	45	49	49	-
9-1-71	48	53	50	37	-
9-15-71	48	51	50	51	-
9-29-71	48	53	52	52	-
10-13-71	49	53	50	51	52
10-27-71	46	49	49	50	51
Mean Value	39.1	40.3	37.2	38.4	35.0

Table 13. Organic carbon concentrations in Summit Creek (mg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	8	8	7	9	6
3-25-71	-	8	8	9	7
4-10-71	7	9	8	9	8
4-28-71	14	20	17	12	13
5-13-71	18	12	11	11	18
6-5-71	10	8	19	9	14
6-22-71	3	3	3	3	3
7-7-71	4	6	3	3	5
7-21-71	4	5	3	1	-
8-4-71	2	4	5	5	-
8-18-71	5	3	8	10	-
9-1-71	4	4	4	5	-
9-15-71	4	3	6	4	-
9-29-71	3	5	6	5	-
10-13-71	3	5	4	4	5
10-27-71	2	1	2	1	4
Mean Value	6.1	6.5	7.1	6.3	8.3

Table 14. **Total phosphorus concentrations in Summit Creek ($\mu g/l$).**

	Sampling Stations				
Date	1	2	3	4	5
3-11-71	72	95	100	126	164
3-25-71	-	84	78	80	86
4-10-71	31	64	86	74	120
4-28-71	26	320	256	232	220
5-13-71	92	180	148	164	188
6-5-71	160	164	104	110	154
6-22-71	76	90	195	110	102
7-7-71	90	74	95	71	98
7-21-71	24	62	33	37	-
8-4-71	21	30	30	37	-
8-18-71	29	30	32	44	-
9-1-71	21	28	20	30	-
9-15-71	18	34	25	32	-
9-29-71	22	25	22	22	-
10-13-71	34	37	25	29	22
10-27-71	43	30	26	37	54
Mean Value	50.6	84.2	79.7	77.2	120.8

Table 15. **Orthophosphate concentrations in Summit Creek ($\mu g/l$).**

	Sampling Stations				
Date	1	2	3	4	5
3-11-71	2.5	3.1	6.2	5.0	2.5
3-25-71	-	5.0	3.7	2.5	4.3
4-10-71	1.8	1.2	1.8	2.5	2.5
4-28-71	1.2	7.4	5.0	3.7	4.3
5-13-71	.6	.6	1.2	1.2	1.2
6-5-71	6.2	6.8	6.8	5.6	6.8
6-22-71	4.3	6.2	6.2	5.6	6.2
7-7-71	4.7	7.4	6.2	3.7	8.0
7-21-71	3.7	31.0	6.2	5.0	-
8-4-71	3.7	10.1	6.2	2.4	-
8-18-71	5.0	7.0	14.3	11.2	-
9-1-71	2.5	12.5	7.0	8.2	-
9-15-71	3.8	12.5	8.0	8.0	-
9-29-71	7.5	7.5	5.0	4.0	-
10-13-71	5.0	5.0	4.5	3.7	4.5
10-27-71	3.2	10.3	7.0	12.5	10.5
Mean Value	3.7	8.5	6.0	5.3	5.0

Table 16. Mass flow of total phosphorus in Summit Creek (lb/day).

Date	Sampling Stations 1	2	3	4	5
3-11-71	3.46	4.56	4.80	6.05	7.87
3-25-71	-	7.93	7.36	7.55	8.12
4-10-71	9.77	20.17	27.10	23.32	37.81
4-28-71	5.05	62.15	49.72	45.06	42.73
5-13-71	70.98	138.87	114.18	126.53	145.05
6-5-71	63.53	65.12	41.30	43.68	61.15
6-22-71	47.15	55.84	120.98	68.25	63.28
7-7-71	21.85	17.97	23.06	17.24	23.79
7-21-71	3.64	9.40	5.00	5.61	-
8-4-71	2.04	2.91	2.91	3.59	-
8-18-71	2.27	2.35	2.50	3.44	-
9-1-71	1.37	1.83	1.31	1.96	-
9-15-71	1.06	2.00	1.47	1.88	-
9-29-71	1.21	1.38	1.21	1.21	-
10-13-71	1.74	1.90	1.28	1.49	1.13
10-27-71	2.32	1.62	1.40	2.00	2.91
Mean Value	15.83	24.75	25.35	22.43	39.38

Table 17. Ammonia nitrogen concentrations in Summit Creek (μg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	58	6	34	22	62
3-25-71	-	52	57	57	50
4-10-71	85	40	73	17	67
4-28-71	100	79	93	61	64
5-13-71	48	77	58	33	56
6-5-71	67	50	87	75	63
6-22-71	9	11	13	15	13
7-7-71	129	18	23	18	33
7-21-71	15	18	18	9	-
8-4-71	11	18	17	41	-
8-18-71	40	17	7	50	-
9-1-71	28	-	4	35	-
9-15-71	23	21	16	13	-
9-29-71	13	12	24	11	-
10-13-71	6	4	7	10	15
10-27-71	10	10	7	7	18
Mean Value	42.8	28.7	33.6	29.6	44.0

Table 18. Nitrite nitrogen concentrations in Summit Creek (μg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	1.9	2.8	3.1	3.3	3.9
3-25-71	-	2.5	3.1	3.6	4.4
4-10-71	2.6	2.1	2.8	2.5	2.5
4-28-71	2.7	4.0	3.5	3.3	4.2
5-13-71	2.5	1.4	2.2	1.5	2.5
6-5-71	3.0	2.0	2.5	3.0	3.6
6-22-71	2.2	2.2	2.0	2.0	2.2
7-7-71	2.0	2.2	2.3	2.2	2.9
7-21-71	2.0	2.3	2.2	2.2	-
8-4-71	1.1	.3	1.0	1.1	-
8-18-71	1.4	1.8	.8	1.1	-
9-1-71	.8	1.3	1.4	1.6	-
9-15-71	.7	2.9	1.2	1.2	-
9-29-71	.8	1.2	1.3	1.4	-
10-13-71	.6	.6	.8	1.1	1.1
10-27-71	.6	.6	.7	1.3	1.6
Mean Value	1.7	1.9	1.9	2.0	2.9

Table 19. Nitrate nitrogen concentrations in Summit Creek (μg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	117	368	242	282	307
3-25-71	-	653	433	429	409
4-10-71	149	252	227	235	234
4-28-71	120	561	308	300	294
5-13-71	97	129	123	141	123
6-5-71	69	118	122	144	132
6-22-71	65	149	127	180	169
7-7-71	51	158	143	213	93
7-21-71	67	197	120	192	-
8-4-71	69	240	134	232	-
8-18-71	73	259	432	466	-
9-1-71	69	288	150	193	-
9-15-71	71	312	144	286	-
9-29-71	50	263	110	459	-
10-13-71	50	397	123	220	164
10-27-71	88	84	200	229	335
Mean Value	80.3	276.8	196.1	262.6	266.0

Table 20. Mass flow of nitrate nitrogen in Summit Creek (lb/day).

Date	Sampling Stations 1	2	3	4	5
3-11-71	5.62	17.67	11.62	13.54	14.74
3-25-71	-	61.65	40.88	40.50	38.61
4-10-71	46.95	79.40	71.52	74.04	73.73
4-28-71	23.31	108.96	59.82	58.27	57.10
5-13-71	74.84	99.53	94.90	108.78	94.90
6-5-71	27.40	46.86	48.44	57.18	52.42
6-22-71	40.33	92.44	78.79	111.68	104.85
7-7-71	12.38	38.35	34.72	51.71	22.58
7-21-71	10.16	29.87	18.19	29.11	-
8-4-71	6.70	23.31	13.01	22.53	-
8-18-71	5.71	20.26	33.79	36.45	-
9-1-71	4.50	18.80	9.79	12.60	-
9-15-71	4.18	18.35	8.47	16.82	-
9-29-71	2.75	14.47	6.05	25.26	-
10-13-71	2.56	20.35	6.30	11.28	8.41
10-27-71	4.74	4.53	10.79	12.35	19.07
Mean Value	18.14	43.43	34.19	42.63	48.54

Table 21. Chloride concentrations in Summit Creek (mg/l).

Date	Sampling Stations 1	2	3	4	5
3-11-71	1.5	1.8	2.3	2.5	3.0
3-25-71	-	2.8	2.3	3.0	3.2
4-10-71	2.8	1.3	2.0	3.2	2.3
4-28-71	2.5	2.5	3.2	2.8	2.0
5-13-71	1.3	1.5	1.8	2.5	2.0
6-5-71	1.5	1.3	2.8	2.8	2.0
6-22-71	2.0	1.8	2.3	2.0	1.8
7-7-71	1.5	2.5	2.8	1.8	2.3
7-21-71	3.0	2.0	2.8	2.0	-
8-4-71	2.0	2.3	1.8	2.0	-
8-18-71	1.8	2.3	2.3	2.8	-
9-1-71	2.0	2.8	1.8	1.8	-
9-15-71	2.3	3.0	3.0	3.3	-
9-29-71	2.3	3.0	3.0	2.8	-
10-13-71	2.3	3.3	2.5	3.0	3.8
10-27-71	2.0	2.8	3.0	3.3	3.8
Mean Value	2.05	2.31	2.48	2.60	2.57

Table 22. Mass flow of chlorides in Summit Creek (lb/day).

Date	Sampling Stations				
	1	2	3	4	5
3-11-71	72.0	86.4	110.4	120.0	144.1
3-25-71	-	264.4	217.2	283.3	302.1
4-10-71	882.2	409.6	630.2	1,008.3	724.7
4-28-71	485.6	485.6	621.5	543.8	388.5
5-13-71	1,003.0	1,157.3	1,388.7	1,928.8	1,157.3
6-5-71	595.6	516.2	1,111.9	1,111.9	794.2
6-22-71	1,240.9	1,116.8	1,427.0	1,240.9	1,116.8
7-7-71	364.2	606.9	679.8	437.0	558.4
7-21-71	454.8	303.2	424.5	303.2	-
8-4-71	194.2	223.4	174.8	194.2	-
8-18-71	140.8	179.9	179.9	219.0	-
9-1-71	130.6	182.8	117.5	117.5	-
9-15-71	135.3	176.4	176.4	194.1	-
9-29-71	126.6	165.1	165.1	154.1	-
10-13-71	117.9	169.1	128.1	153.8	194.8
10-27-71	107.9	151.1	161.9	178.0	205.0
Mean Value	403.4	387.1	482.1	511.7	558.6

Table 23. pH values in Summit Creek.

Date	Sampling Stations				
	1	2	3	4	5
3-11-71	8.15	8.15	8.15	8.15	8.05
3-25-71	-	8.35	8.30	8.25	8.45
4-10-71	7.90	8.15	8.05	8.10	8.20
4-28-71	8.10	8.15	7.85	8.20	8.05
5-13-71	8.20	8.20	8.05	8.10	8.30
6-5-71	8.35	8.10	8.15	8.05	8.30
6-22-71	8.00	8.05	8.10	8.05	8.05
7-7-71	8.20	8.35	8.45	8.40	8.65
7-21-71	8.45	8.25	8.45	8.35	-
8-4-71	8.30	8.40	8.45	7.90	-
8-18-71	8.45	8.45	8.40	8.40	-
9-1-71	8.60	8.45	8.60	8.40	-
9-15-71	8.55	8.65	8.70	8.75	-
9-29-71	8.55	8.50	8.65	8.65	-
10-13-71	8.60	8.65	8.70	8.65	8.70
10-27-71	8.50	8.50	8.60	8.60	8.65
Mean Value	8.33	8.33	8.35	8.31	8.34

Table 24. Temperature values in Summit Creek, °C.

Date	Sampling Stations 1	2	3	4	5
3-11-71	6.0	6.5	5.5	5.5	5.5
3-25-71	-	7.0	7.5	8.0	8.0
4-10-71	7.5	8.0	9.0	9.0	9.5
4-28-71	8.0	9.5	10.0	10.0	10.0
5-13-71	7.5	8.5	9.0	9.0	9.0
6-5-71	7.0	8.0	9.0	9.0	9.5
6-22-71	7.5	9.0	10.0	10.0	10.5
7-7-71	11.0	12.0	13.0	13.0	18.5
7-21-71	10.0	12.0	13.0	13.0	-
8-4-71	10.0	12.5	14.5	14.5	-
8-18-71	10.0	13.0	13.5	14.0	-
9-1-71	11.0	13.0	14.0	14.5	-
9-15-71	9.5	11.0	12.0	12.5	-
9-29-71	7.5	8.5	8.0	8.5	-
10-13-71	5.5	7.0	7.0	7.5	7.5
10-27-71	4.0	5.0	4.5	5.0	5.0
Mean Value	8.1	9.4	10.0	10.2	9.3

Appendix B

Calculation of Quantities of Septic Tank Effluent Required to Account for Increases in Coliform Counts Observed from Station 3 to Station 4

Use – $\dfrac{10^{10}\ \text{coliforms}}{\text{person-day-gal of effluent}}$

Average Flow in Stream – 10 cfs = 6,462,720 gal/day

$$\text{Increase between Stations 3 and 4} = 286.4\ \frac{\text{coliforms}}{100\ \text{ml}} \approx \frac{11{,}500\ \text{coliforms}}{\text{gal. of stream water}}$$

$$\frac{\text{Volume Required}}{\text{day}} = \frac{\left(11{,}500\ \frac{\text{coliforms}}{\text{gal}}\right)\left(6{,}462{,}720\ \frac{\text{gal}}{\text{day}}\right)}{10^{10}} \approx 7.5\ \text{gal/day*}$$

*Note: This value was obtained assuming the effluent is discharged directly into the stream and that no die-away of the organisms has occurred.

Appendix C

Calculation of Total Phosphorus Contribution of Animals in Feedlots

Assume: Average Weight

Pigs - 250 lbs

Cattle - 1000 lbs

Assume: Cattle and Pigs contribute equally on a per 100 lbs of animal weight basis.

Total Animal Weight = (25 x 1000) + (10 x 250) = 27,500 lbs

Average increase in Total-P attributed to animals = 24.75 lbs/day - 15.83 lbs/day = 8.92 lbs/day

Contribution of Total-P in lbs/day per 100 lbs of animal weight

$$= \frac{8.92 \text{ lbs/day}}{27{,}500 \text{ lbs of animal wt.}}$$

$$= \frac{0.032 \text{ lb/day}}{100 \text{ lbs of animal wt.}}$$

Appendix D

Calculation of Nitrate Nitrogen Contribution of Animals in Feedlots

Total Animal Weight (same as in Appendix C) = 27,500 lbs

Average Increase in Nitrate-N from Station 1 to Station 2 = 43.43 lbs/day - 18.14 lbs/day

= 25.29 lbs/day

Contribution of Nitrate Nitrogen in lbs/day per 100 lbs of Animal Weight = $\frac{25.29 \text{ lbs/day}}{27{,}500 \text{ lbs of animal weight}}$

= .092 lbs/day per 100 lbs of animal weight

Appendix E

Calculations of Daily Septic Tank Effluent Discharge Volumes Required to Increase Chloride Concentration 1 mg/l

Assume:

Stream flow rate = 10 cfs

Effluent chloride concentration = 140 mg/l

Effluent flow from average household = 400 gal/household-day

$$\text{Volume required/day} = \frac{(1\ \text{mg/l})(10\ \text{cfs})(7.48\ \text{gal/cu ft})(86{,}400\ \text{sec/day})}{(141.0\ \text{mg/l})}$$

$$= 45{,}800\ \text{gal/day}$$

$$\text{Equivalent households} = \frac{45{,}800\ \text{gal/day}}{400\ \text{gal/household-day}} = 115$$